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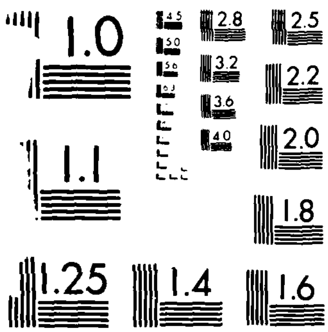

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ENVIROSAT–2000 Report

NOAA Satellite Requirements Forecast

May 1985

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service

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Environmental satellites have been an essential component of NOAA's global observing system for 25 years. This report offers a projection of NOAA's requirements for satellite data and services covering the next 15 years. These requirements derive from the mission responsibilities of NOAA's public service and research agencies: the National Weather Service, the National Ocean Service, the National Marine Fisheries Service, and the Office of Oceanic and Atmospheric Research. The National Environmental Satellite, Data, and Information Service operates the Polar-orbiting Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellite (GOES) systems and provides data archive and distri-

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ENVIROSAT—2000 Report

NOAA Satellite Requirements Forecast

W. John Hussey, Editor

Contributors:

D. Cotter, NESDIS
L. Fisher, NMFS
D. Montgomery, NOS
T. Pyle, OAR
F. Zbar, NWS

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May 1985

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
Anthony J. Calio, Deputy Administrator

National Environmental Satellite, Data, and Information Service
John H. McElroy, Assistant Administrator

NOAA SATELLITE REQUIREMENTS FORECAST

ABSTRACT

Environmental satellites have been an essential component of NOAA's global observing system for 25 years. This report offers a projection of NOAA's requirements for satellite data and services covering the next 15 years. These requirements derive from the mission responsibilities of NOAA's public service and research agencies: the National Weather Service, the National Ocean Service, the National Marine Fisheries Service, and the Office of Oceanic and Atmospheric Research. The National Environmental Satellite, Data, and Information Service operates the Polar-orbiting Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellite (GOES) systems and provides data archive and distribution services to the public and private sectors. The satellite support needed to help meet their mission goals through the end of this century are presented as they have been identified by each agency. The requirements specified in this report will be a major factor in the long-range planning for NOAA's future satellite programs.

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I. INTRODUCTION

The purpose of this report is to provide a consolidated projection of the requirements of the National Oceanic and Atmospheric Administration (NOAA) for operational environmental satellite support through the end of this century. This projection is the sum of the anticipated requirements of the public service and research agencies of NOAA--the National Weather Service (NWS), the National Ocean Service (NOS), the National Marine Fisheries Service (NMFS), and the Office of Oceanic and Atmospheric Research (OAR). The National Environmental Satellite, Data, and Information Service (NESDIS) operates NOAA's satellites and manages the systems that provide satellite data product delivery and archives. NESDIS does not have satellite data requirements that are independent of the other NOAA agencies.

The service and research agencies of NOAA are chartered to provide public benefits through the analysis, forecast, and study of Earth environmental conditions and the solar influences that impact on them. These NOAA agencies also operate systems for observing the state of the Earth environment and the sun, exchange similar observations with others, and support the archives that maintain accessibility to the observations. At the core of each of these NOAA functions is the observational data base. The data base either serves as a prime tool for the activities of the function or is, itself, the object of the function.

NOAA mission responsibilities are the basis for establishing the requirements for the data base. Usually the service agency states its data needs in terms of the types of measurements required and specifies the frequency, timeliness, distribution, and skill of measurement called for by current practices and practical considerations, such as resources available. Sometimes agencies state their data requirements as specific levies against observing systems that are planned for implementation. Because data needs are usually satisfied from a mix of observing systems, final decisions about data sources consider alternate data collection methods. One of the papers in this ENVIROSAT-2000 series (<u>The U.S. Weather Watch: A Composite System</u>) further discusses observing system alternatives and their respective roles.

The satellite requirements expressed in this report have been provided by the data-using agencies of NOAA to help develop a long-range plan for conducting NOAA's satellite activities. This approach is not the usual one, because the agencies were

required to focus on their future requirements for data from a particular future observing system, without the benefits of parallel long-range planning for data support from complementary or competing observing systems. The agencies judged the emerging capabilities of satellites and other observing systems to identify the likely role of satellites in satisfying future mission requirements. In all cases, the agencies recognize that the feasibility of meeting their future needs by satellite or other systems will depend upon the technological progress and funding conditions that exist in coming years.

The satellite data and service requirements that have been specified by the NOAA user agencies reflect their mission assignments. To provide context for this report, these missions are stated briefly, as follows:

- The National Weather Service mission is to monitor and predict the state of the atmospheric and hydrologic environment. NWS observes and reports weather, river, and ocean conditions of the United States and its possessions, and issues warnings and forecasts of weather, flood, and ocean conditions. It operates national meteorological, hydrological, and oceanic service systems; provides climatic data products; and issues warnings of severe weather to government, industry, and the general public. NWS is responsible for public weather support during civil emergencies, conducts postdisaster surveys, and cooperates with the Department of Defense (DOD) in the event of a declared national emergency. NWS discharges the Federal coordinating functions assigned to NOAA for meteorology and marine prediction services. It performs applied meteorological research; assists in developing community awareness for weather-related natural disasters; and participates in international meteorological activities, including the exchange, coding, and monitoring of data forecasts.

- The National Ocean Service mission is to provide ocean and coastal zone management services and information products in support of national needs. NOS provides services and products to support the development and utilization of the oceans and the management of marine and coastal resources. It promotes improvements in marine and coastal commerce and the safety of marine and coastal activities. It facilitates the development of ocean mineral resources and energy, and conducts national assessments of marine resource utilization. NOS provides services, predictions, and warnings, as well as maps, charts, and publications, to assure safe use of U.S

marine waters and air space. It carries out NOAA's responsibilities in marine environmental quality research, development, and monitoring. NOS furnishes marine operational support to other NOAA components and administers NOAA's coastal zone management, coastal energy impact, and marine and estuarine sanctuary programs. NOS manages programs in physical, biological, chemical, and geological oceanography that support the ocean services program, lead to better understanding of the marine environment, and provide a scientific information base for the development of national policy on the oceans and their uses.

- The National Marine Fisheries Service mission is to promote the conservation, management, and development of living marine resources for commercial and recreational uses. It implements programs to assist the U.S. fishing industry in enhancing production and marketing, and developing positions on international fisheries issues. NMFS assesses and provides guidance on the conservation and protection of marine mammals and their habitats, and on matters related to the environmental impact of human activities on living marine resources. It coordinates aquaculture research, and contributes advice on the socioeconomic condition of fisheries and the quality, safety, and use of their products.

- The Office of Oceanic and Atmospheric Research mission is to conduct laboratory and extramural research projects that are relevant to NOAA's service and resource management programs, and that provide sound technological and scientific principles on which to base improvements of those services and products. OAR coordinates research programs throughout NOAA to ensure their compatibility and effectiveness in serving NOAA's program needs. It conducts research to promote a better understanding of the atmospheric, coastal and oceanic, and geophysical processes that underlie the service and information products of NOAA's service-oriented components.

The NOAA responsibility for civil operational satellite activities includes the management of resident satellite systems and the coordination of access to the satellite data of systems operated by others. The satellite support requirements of NOAA's user agencies usually are met through the resources of NOAA's own operational satellite systems, both environmental (POES and GOES) and land-observing (Landsat); however, this is not exclusively the case. The National Aeronautics and Space Administration (NASA) research and development satellites contribute, as do those of the DOD Defense Meteorological Satellite Program (DMSP) and foreign system operators. Data from NASA systems are obtained under interagency agreements,

and foreign system data are obtained either through international bilateral or World Meteorological Organization (WMO) agreements or exchanges. Agreements between NOAA and DOD assure data product interchanges that benefit each. For example, the mechanics of NOAA access to the data products of the Navy Remote Ocean Sensing Satellite (N-ROSS), to be launched in 1990, are being developed now. The future satellite support needs of NOAA agencies will be met by the continuation of access to data from satellites managed by NOAA and other operators.

The normal operational array of NOAA satellites is two Polar-orbiting Operational Environmental Satellites (POES), two Geostationary Operational Environmental Satellites (GOES), and one Landsat. Under present planning and budgets, POES and GOES will be continued into the 1990's, with a next-generation GOES introduced about 1989 and a next-generation POES early in the next decade. It is anticipated that Landsat will be continued as a Government function, under commercial operation, until the end of the design life of Landsat 5 (about mid-1987). The Government's Landsat contractor will operate the system, be responsible for marketing Landsat products, and provide the next-generation (Landsat 6 and 7) satellites. The current and planned capabilities of NOAA's satellites are given briefly in Appendix A.

The long lead times that precede the implementation of operational satellite systems make it possible to anticipate many of the technical opportunities that could become available to Earth remote-sensing satellite programs by the mid-1990's. These opportunities are unfocused at the moment because Federal and international decisions concerning them are only now being considered. This report should help sharpen that focus. Other papers in the ENVIROSAT-2000 series discuss future technology, including the options opened by the U.S. commitment to the Space Station, as well as the satellite data needs of the other Federal user agencies and the future role of ground-based observing systems. This report contributes to the outlook of decision makers by providing a perspective on the requirements that are important to national programs for protecting life and property and improving social and economic conditions.

II. INTEGRATION OF DATA REQUIREMENTS

Operational missions of the National Weather Service (NWS) and the National Ocean Service (NOS) require them to provide daily environmental advice and information that impact the safety and economic well-being of individuals and United States interests. Because of this impact, their data requirements exert the strongest influence on the designs of NOAA's operational observation systems, including satellite systems. The data needs of the National Marine Fisheries Service (NMFS) are related to operational assessments and advice rendered to Government entities and the NMFS user community. The additional data needs of NMFS are accommodated in NOAA's operational observation systems wherever practical. The Office of Oceanic and Atmospheric Research (OAR) is NOAA's research and development arm. It is not always possible to satisfy OAR's special needs for data from operational observation systems. When and where possible, however, OAR's special data needs are served by designing the systems to be responsive to OAR requirements, usually on the basis of noninterference with the system's primary operational objectives.

This chapter provides an integration of the satellite data requirements of the four NOAA user agencies, which are discussed in detail in the following four chapters. The purpose is to highlight the similarities and differences among these requirements and show how they are integrated for the long-range satellite planning process. The requirements are discussed with respect to major categories of products, such as cloud cover, vertical temperature profiles, winds, and sea surface temperatures.

Table II-1 provided at the end of this chapter lists the primary NOAA requirements for satellite observations. This table was developed from the detailed requirements discussed in subsequent chapters for each NOAA user agency. Table II-1 is not intended to be a complete listing of all NOAA requirements but rather a synopsis of the most important observations toward which space-based remote sensing can contribute. Tables II-2 and II-3 illustrate the temporal progression of NOAA satellite product and service improvements. Table II-2 shows this progression for the geostationary system and Table II-3 shows the expected progression of the polar-orbiting system.

A. ATMOSPHERIC OBSERVATIONS

1. Cloud Cover

Day and night measurements of global and regional cloud cover are needed by NWS, NOS, and OAR. Satellite systems that meet

NWS regional coverage requirements for Geostationary Operational Environmental Satellites (GOES) spatial resolutions of 1 km visible and 4 km infrared, at a frequency of 5 to 30 minutes, automatically satisfy the primary regional requirements of NOS and OAR. Additionally, there is a stated OAR Program for Regional Observing and Forecasting Services (PROFS) requirement for infrared GOES imagery at 2 km resolution. On the global scale, resolutions of 4 to 10 km are needed to provide cloud coverage measurements, accurate within 10 to 20 percent, for use in models with 50 to 250 km grids. Global coverage observations are needed two to four times a day to support these models, with data timeliness keyed to the scheduled run times of the computations.

2. Vertical Temperature Profiles

The requirements of NWS, NOS, and OAR for the mean temperatures of atmospheric layers are similar: accuracies of 1 to 2.5 ^{o}C for layers 500 to 1,500 m deep, ranging to altitudes of 30 to 45 km. Temperatures for 40 layers are required by NWS now, and will climb to more than 60 layers in the 1990's. A horizontal resolution of 10 km is desired. NWS uses data to the 30 km level for numerical weather prediction and data for the layers above for climate change monitoring. Observations two to four times a day are needed for NWS operational global models; eight observations a day meet severe weather monitoring needs for the continental U.S. An ability to repeat GOES temperature soundings every 30 minutes over threatened U.S. areas is required by NWS. OAR has a requirement for vertical resolutions of 300 m for some applications. The three agencies need sounding data from cloud-covered areas where satellite infrared sensors are ineffective below cloud tops.

3. Atmospheric Humidity Profiles

NWS, NOS, and OAR require information about the vertical distribution of atmospheric water vapor on global and regional scales. Expressed either in terms of layer moisture (g/cm^3) or relative humidity (percent of saturation in a layer), the requirements are for measurements accurate within 10 to 30 percent for several significant layers from the surface to the 50 mbar level. The NWS need for half-hourly measurements at 10 km resolution over the continental U.S. also satisfies the continental U.S. coverage needs of NOS and OAR. Regional NWS applications for other areas are satisfied by observations every 2 to 4 hours at resolutions of 10 to 50 km. On the global scale, measurements are needed two to four times a day at resolutions of 50 to 250 km for NWS and OAR.

4. Winds

Requirements for wind observations are broad. NOS states a need for boundary layer wind measurements over oceans that are accurate to 0.5 m/s on a 5 km grid. OAR needs regional and global wind measurements accurate to 1 to 3 m/s on 10 to 50 km grids. The ability to satisfy these requirements would accommodate NMFS and NWS needs. At present, winds inferred from cloud motions in a time series of GOES images are used to meet NWS regional needs for 2 to 7 m/s accuracy, four times per day, on a 350 km grid. Very advanced sensors will be necessary to obtain the wind measurements that are being called for in this report.

5. Precipitation

The occurrence and rate of precipitation, and the amount of precipitable water in an atmospheric column, are information elements needed by NWS and OAR. Precipitable water estimates, at 7 km resolution and accurate to 30 percent, on a 50 km U.S. grid, are needed hourly by NWS for continental U.S. applications. OAR needs global, coarse assessments of the times and rates of precipitation.

B. OCEANIC OBSERVATIONS

1. Sea Surface Temperature

The NWS requirement for global sea surface temperatures (SSTs) calls for 2 ^{o}C accuracy at 25 km horizontal resolution, with measurements made every 3 days. NMFS and NOS need daily global observations at 1 ^{o}C accuracy on a 5 to 10 km grid. SSTs for U.S. coastal waters are needed at 1 ^{o}C accuracy and 8 km resolution by the NWS, and 0.5 ^{o}C accuracy and 1 km resolution by NMFS and NOS. OAR states that accuracies of 0.1 to 0.5 ^{o}C are needed for climate research and detection of the onset of anomalies such as El Niño events.

2. Sea Surface Currents

The ability to detect sea surface currents at resolutions of 50 km or less, and to determine their speeds to an accuracy of a few centimeters per second, is called for by NWS, NOS, and NMFS requirements. NOS has needs for resolutions as small as 5 km in this regard, and sees the need for some observations as often as every 6 to 48 hours. NOS would use the finer detail to determine the wind, thermal, and geostrophic components of surface ocean currents. Monthly observations satisfy NWS needs.

3. Sea and Lake Ice

Sea ice coverage, measured to 2 percent accuracy at 50 km resolution every 3 days, is an NWS requirement. NOS and NMFS also require estimates of sea and lake ice extent and thickness. NOS needs regional coverage at 5 km resolution on a daily basis. OAR is interested in obtaining measurement of ice albedo.

4. Ocean Surface Topography

NOS ocean observation requirements include ice height above the sea surface. Along with NMFS, NOS also needs wave height and direction information, as well as data about tides.

C. ENERGY BALANCE

NWS, NOS, and OAR have requirements for measurements relating to heat exchange between the oceans and atmosphere, the atmosphere and space, and within the atmosphere. Earth's albedo is a prominent measurement requirement. Because energy balance is a global question requiring a global review, satellites are the primary source of data for satisfying these requirements.

D. OTHER MEASUREMENTS

Among other satellite-derived requirements that are expressed by the NOAA user agencies and deserve mention here are:

- Snow cover, measured weekly over the Northern Hemisphere at 1 km visible resolution, for use by NWS and OAR

- Total ozone and its changes, for NOAA (OAR) climate and NWS operational purposes

- Cloud-top heights, especially over the continental U.S., for NWS severe weather monitoring programs

- Soil moisture estimates for OAR, which will be made possible by the introduction of the Advanced Microwave Sounding Unit (AMSU) on NOAA I

Table II-1
Integrated Primary Requirements for Satellite Observations*

Observation**	Accuracy	Grid	Frequency	Coverage	Requestor
Cloud cover imagery	1 km Vis, 4 km IR	--	5-30 min	Regional (GOES)	NWS, NOS, OAR
	4-10 km, Vis and IR	50-250 km	6-12 hours	Global	NWS, NOS, OAR
Vertical temperature profiles	1-2.5 °C for layers 500-1500 m deep	10 km	6-12 hours	Global	NWS, NOS, OAR
		10 km	30 min	Regional (GOES)	NWS
Atmospheric humidity	10-30% several layers	50-250 km	6-12 hours	Global	NWS, NOS, OAR
		10-50 km	2-4 hours	Regional (GOES)	
		10 km	30 min	Conus***	
Winds	1-3 m/s (above boundary layer)	10-50 km	6-12 hours	Regional/global	OAR, NWS, NMFS
	2-7 m/s (cloud motions)	350 km	6 hours	Regional (GOES)	NWS
	0.5-2 m/s (boundary layer)	5-20 km	3-12 hours	Regional/global	NOS
Quantitative precipitation estimates	20%	50 km	Hourly	Conus/global	NWS, NOS, OAR
Precipitable water	30%	7 km	Hourly	Conus	NWS
Sea surface temperature (SST)	2 °C	25-50 km	1-3 days	Global	NWS, NOS
	1 °C	5-10 km	Daily	Global	NMFS, NOS
	0.5-1 °C	1-8 km	12-24 hours	U.S. coastal waters	NWS, NOS, OAR, NMFS

* This table is a synopsis of the primary NOAA requirements for satellite observations. It is not intended as a complete listing of the requirements included in subsequent tables.

** The observations included are not listed with respect to priority.

*** Contiguous 48 states.

Table II-1 (concluded)
Integrated Primary Requirements for Satellite Observations

Observation	Accuracy	Grid	Frequency	Coverage	Requestor
Sea surface currents	2-10 cm/sec	50-100 km	2-7 days	Global/regional	NWS, NOS, OAR, NMFS
	20 cm/sec	50-100 km	Monthly	Critical areas	NWS
Sea/lake ice:					
Edge	1 km	Line position	1-3 days	Regional/global	NOS, OAR, NWS, NMFS
Cover	2%	1-50 km	1-3 days	Regional/global	NOS, OAR, NWS, NMFS
Thickness	10 cm	1-50 km	1-3 days	Regional/global	NOS, OAR, NWS, NMFS
Type (age)	Age category	1-50 km	1-3 days	Regional/global	NOS, OAR, NWS,
Height	1 m	0.001-1 km	3 hours	Coastal/regional/ global	NOS, OAR, NWS
Water color/ chlorophyll concentration	30% in mg/l	1 km	Daily	U.S. coastal waters	NOS, NMFS, NWS, OAR
Turbidity	30% in g/m^3	1 km	12 hours	U.S. coastal waters	NOS, NMFS
Sea surface topography	2 cm	10-100 km	6-12 hours	Regional/global	NOS, OAR, NWS
Wave height	0.5 m	10-100 km	3-12 hours	Coastal waters, regional, global	NOS, NWS, OAR
Sea surface heat exchange	10-50 W/m^2	10-100 km	6-12 hours	Regional/global	NOS, NWS, OAR
Net radiation	20 W/m^2	2.5° lat./long.	Daily	Global	NWS
Snow cover	15 km^2	2-20 km	Biweekly	North America	NWS, OAR
Total ozone	10 Dobsons	—	3 hours	Mesoscale	OAR
Space environment monitoring		(See detailed requirements in Table V-7)			OAR

Table II-2
NOAA Geostationary Satellite Products and Services

Product/Service Category	Present Capability	GOES G and H	GOES-Next	Beyond
Imagery	30 min Vis and IR (15 min for severe weather)	Same	Independent imaging and sounding	Further improved resolution and pixel registration
	4 per day water vapor images		Improved Earth location	
	Vis: 1 km resolution		Increased imaging channels to 5	
	IR: 8 km resolution		Improved IR resolution	
Soundings (VAS)	Demonstration mode (12 channels)	Operational VAS ground system	Increased sounding channels to 14 Increased sounding resolution	High resolution infrared interferometer sounder (HIS)
	Multispectral imagery		More rapid sounding over smaller areas of interest	Microwave sounder
Data collection services	12,000 messages/hour	Same	Improved ground system	Additional channels and higher data relay rates
Space environment monitoring	Magnetometer	Same	Solar x-ray imager	Same
	Solar x-ray sensor			
	Energetic particle sensor (EPS)			
Weather facsimile service	WEFAX 1691 MHz	Same	Same	Digital WEFAX

Table II-3
NOAA Polar-orbiting Satellite Products and Services

Product/Services Category	Present Capability	NOAA K, L, and M	Space Station Polar Platform
Soundings	TOVS: HIRS/2 - 20 channels SSU - 3 channels MSU - 4 channels	AMSU (all weather) A - 15 channels B - 5 channels	Advanced AMSU limb sounder
	Direct Sounder Broadcast (DSB)	Improved HIRS/2	Same
Imagery	AVHRR/2 (Vis and IR): 5 channels	Add 1.6 μm channel; time share with 3.8 μm channel	Ocean color instrument (OCI), medium resolution imaging radiometer (MRIR), moderate resolution imaging spectrometer (MODIS), and synthetic aperture radar (SAR)
	HRPT - 1.1 km resolution APT - 4 km resolution	HRPT/APT same	
Data collection and platform location service	ARGOS: Random access system platform location service 2500 platforms/day	Improved ARGOS II 5000 platforms/day	Same
Space environment monitoring	SEM: TED: 0.3-20 keV (11 bands) MEPAD: 30-60 keV HEPAD: 370-850 MeV	Same	Same
Vertical distribution of ozone in atmosphere	SBUV/2	Same	Global ozone monitoring radiometer (GOMR)
Earth emitted longwave radiation	ERBE	Same	Same
Search and rescue service	SARSAT EPIRB bands 121.5 MHz 243 MHz 406 MHz	Improved system	Same

III. SATELLITE REQUIREMENTS
OF THE
NATIONAL WEATHER SERVICE

III. SATELLITE REQUIREMENTS OF THE NATIONAL WEATHER SERVICE

This chapter states National Weather Service (NWS) requirements for satellite data, products, and services for usage projected to the year 2000. It is recognized that these requirements must still be measured against the technological and financial feasibility of meeting these service needs.

Most requirements stated in this document have been under development for some time. NWS requires timely data regardless of the source. The requirements are driven by the utility of the data in meeting the NWS mission. The requirements in this document represent projections of future satellite-derived data that may meet the NWS need. These data may be derived from NOAA's Visible and Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS) capabilities, the characteristics of the next generation of geostationary and polar orbiters, including future oceanographic satellites, and requirements for the delivery of satellite information to NWS offices. The requirements do not represent a radical departure from previously expressed requirements, since they draw heavily upon existing official and previously coordinated statements of need. Any actions to meet a requirement expressed for the year 2000 time frame need to be under way, as major programs require extremely long lead times to be implemented.

Satellite data requirements result from the specific goals set by NOAA in response to its mandated missions. Foremost among NWS goals requiring satellite data for their achievement are:

- The provision of timely, accurate, and cost-effective public warnings and forecasts of severe weather events, to reduce the potential loss of life and property and to advance the national economy

- The provision of aviation, agricultural, and marine weather services aimed at increasing U.S. productivity

Satellites are virtually the "glue" that holds the Global Observing System (GOS) together. They provide key observations in data-sparse areas and communicate data from other types of observing systems. There will be a continued need through the 1990's for increased quality of soundings and products of higher spatial and temporal resolution for global forecasting (numerical weather prediction) and climate services. In addition, satellites provide the best opportunity to obtain global data fields of surface characteristics over the oceans. These fields are particularly important in deriving wind, wave, and ice information needed for warnings and

forecasts. Also, provisions for more extensive worldwide sharing of the available satellite information will be needed.

Wider access to imagery and derived products also will be required during the 1980's and 1990's. The expanded need for imagery and derived products stems from the NWS desire to improve warnings, forecasts, and services for events such as severe thunderstorms, tornadoes, and flash floods that are short lived but devastating. The need will be most intense for the smaller scale of atmospheric motion often correlated with severe weather. High-resolution (in space and time) information can be provided cost effectively only by remote-sensing observation systems. Combinations of data from ground- and space-based systems currently appear to be the most likely candidates to satisfy these needs. These include satellite observing systems, ground radars, sounders, data buoys, and ships, in complementary fashion. Equally important in satisfying these observational requirements is the timely provision of the information to various NWS offices. Availability is the key to improving services.

In summary, the future use of satellite data will be characterized by:

- Expanded operational use
- Increased demand for improved reliability and immediate availability of products to the forecaster
- Emphasis on short-period hydrometeorological forecasts and warnings over local areas
- Increased use of digital data on global, national, and local scales
- Flexibility for growth, development, and research
- Accompanying developments in communications, dissemination, meteorological interpretation, and display systems
- Increased observations of ocean areas previously not available
- Enhanced information on ocean circulation and other data needed for climate research

A. ASSUMPTIONS AND CONSTRAINTS

A number of assumptions have been made and constraints have been imposed for the purposes of this document. The overall mission of NWS through the year 2000 is assumed to remain the same, with more detailed and extensive services expected

during this period as a result of new capabilities in science and technology.

The requirements, for the most part, are restricted to NWS needs. In certain areas, applied research is under way in closely coupled programs of the Environmental Research Laboratories (ERL), National Environmental Satellite, Data, and Information Service (NESDIS), and National Ocean Service (NOS). These programs, which include VAS, Profiler, and the Program for Regional Observing and Forecasting Services (PROFS), are expected to have a major impact upon NWS observing and processing capabilities. These requirements are included to highlight their importance and identify NWS expectations. On a related issue, NWS does not expect satellite data to replace conventional observations, but they will complement and enhance the ground and airborne observing systems.

It is assumed, for planning purposes, that other nations will maintain, and in some cases increase, their satellite contributions to the maintenance of the Global Observing System. Access to the Japanese Geostationary Meteorological Satellite (GMS), the European Space Agency's (ESA's) Meteosat and other geostationary systems is within the scope of NWS requirements, as is access to data from U.S. military weather and ocean satellites such as the Defense Meteorological Satellite Program (DMSP) and the Navy Remote Ocean Sensing System (N-ROSS). In addition, it is assumed that NWS will have access to ocean satellite information, such as from the ESA Remote-Sensing Satellite (ERS-1), from other countries. Excluded are Earth resource sensing systems such as Landsat.

Studies are still under way to determine the most cost effective specific technical solution for large-scale communication of observation information and forecasts in both NWS and NESDIS. However, it is assumed that, in general, satellites will continue to play a central and expanding role in providing these capabilities [e.g., Aircraft to Satellite Data Relay (ASDAR), data buoys, Shipboard Environmental (Data) Acquisition System (SEAS), hydrologic information]. Therefore, they are included in the document.

Every effort has been made to make judgments about requirements that are consistent with technological and financial realities. Still, there is no guarantee that the statement of requirements satisfies that constraint in all areas.

B. CONTEXT OF THE REQUIREMENTS

The NWS requirements for space-based remote-sensing capabilities, as stated in Section C, emerged from the following considerations: 1) the state of the art and science of environmental forecasting, its expected evolution over the

next 15 years, and assessments of the cost and capabilities of space-based systems to support and promote that evolution; 2) the strengths of the other major observing systems in the overall observational network [ground-based Profilers, radars, data buoys, Automated Surface Observing Systems (ASOS), etc.], how these systems complement one another, and how they are best complemented by satellite systems; 3) the plans for improving NWS information and communications, and the needs and impacts related to the handling of satellite data by these systems; and 4) the anticipated organization changes needed to improve efficiency and effectiveness of operations, and the potential of satellite systems to support those changes.

1. Advances in Science

Advances in environmental forecasting are closely coupled with improvements in observing systems. The quality of computer-generated forecasts and guidance to forecasters is in large measure dependent upon the quality and completeness of the data that are used to define initial conditions for numerical models. Also, the ability of forecasters to detect and monitor the growth and decay of severe local weather while these events are under way is directly linked to their rapid access to high-resolution information on a storm and its environment.

The course of scientific advances over the next decade can be gauged by the kinds of research and development programs that are under way or being planned. While numerous international and national efforts are important in their own right, it is the current scientific interest in mesoscale research for atmosphere and oceans that holds the greatest potential for improving NWS forecasting operations through the 1990's.

Scientific advances over the next 15 years, in large- and small-scale modeling, and in very short-range prediction techniques, will depend greatly on the availability of accurate measurements derived from satellite-based sounding and imaging instruments and the ability to assimilate the data from these systems.

2. Other Observing Systems

Just as there must be a balance of resources among the major components of the forecasting process (i.e., observation, data assimilation, decision making, product formulation, and product dissemination), there also needs to be a balance among the various elements of these components. Thus, in considering observations, the types of systems in use and those under development must be surveyed, and the strengths and weaknesses of each must be assessed, to promote development of the most effective observing network.

Of primary concern to NWS is the integration of the following major observing systems: the Next-Generation Weather Radar (NEXRAD), the Automated Surface Observing System (ASOS), the Profiler network, the Automated Radio Theodolites (ART), and the next generation of geostationary and polar-orbiting satellites (GOES-Next and NOAA K, L, and M). Also, it is anticipated that oceanic satellite data from N-ROSS, ERS-1, and other similar observing systems will need to be integrated with conventional observing systems. To accomplish the needed data integration within the time constraints of operational forecasting, the requisite preprocessing must be done before the data are acquired by NWS information systems. This is especially true for satellite data, which must be calibrated and Earth-located to accommodate the changing location and performance of the sensors.

3. Information and Communication System Plans

NWS has a program for an Advanced Weather Interactive Processing System for the 1990's (AWIPS-90). The goal of the AWIPS-90 program is to implement a highly automated, integrated information processing, communication, and display system to support the operational demands of NWS field offices and national centers in the 1990's.

Systems such as NEXRAD; ASOS; GOES-Next; NOAA K, L, and M; Profiler; data buoys; SEAS; oceanic satellites; and ART will, in fact, be the NWS observing systems through the year 2000 and will provide a wealth of data. The major task remaining is to develop communications links and processing systems to transform these data into true information.

In addition to preprocessing satellite data, effective methods must be developed for centrally extracting the most meaningful information from the abundance of raw data. Processing resources in the field should be dedicated to using information to analyze and forecast the weather, and not to process raw observational data.

4. Organizational Directions

The NWS plan to modernize and restructure field organization is in progress. Under this plan, NWS will strive to meet increasing demands for more timely and accurate warning and forecast services under tight financial and personal constraints. The key to this effort is the incorporation of current and emerging technologies for observations, communication, interactive processing, and modeling. More automated methods for acquiring observational data and the availability of more timely and comprehensive meteorological and hydrological data are critical to enable NWS to consolidate warning

and forecast hydrological operations at a significantly reduced number of field offices.

C. GEOSTATIONARY AND POLAR-ORBITING SATELLITE REQUIREMENTS

This section details requirements, both current and future, for both geostationary and polar-orbiting satellites. Also addressed are particular aspects of NWS service programs that require specific products.

1. Current Operational NWS Requirements for Geostationary Satellite Data Products and Services

The principal requirements for geostationary data and services are:

- Continual monitoring and tracking of the development, motion, and intensity of severe storms, including hurricanes, tornadoes, severe thunderstorms, and squall lines, using visible, infrared (IR), and moisture channel imagery

- Routinely providing a full-disk view of the Earth every 30 minutes in the visible and infrared spectra, from which sectors are produced; smaller sectors can be viewed every 15 minutes for the derivation of mesoscale cloud motion winds and severe storms monitoring

- Providing image distribution to users in near-real time, which includes the division of the full-disk image into selectable sectors covering special and routine areas of interest

- Collecting, interrogating, and relaying environmental data from instrumented platforms to a central site for processing and delivery to the platform owners/operators

- Providing a weather facsimile (WEFAX) broadcast service to ground stations within radio range of the satellite

The principal sensing instrument on the GOES satellites is the VAS. Major communication capabilities include the GOES Data Collection System (DCS), the direct transmission of VAS data, and the WEFAX service.

The function and operation of each of these systems are discussed in this section, as are the products and services they produce. NWS uses of these outputs are also described. The products and services produced from these systems form the present NWS requirements for geostationary satellites.

a. <u>VISSR Atmospheric Sounder (VAS).</u> The VAS has both an

imaging and a sounding capability, and provides near-continuous cloud viewing (images) with ground resolution of 1 km in the visible and 7 to 14 km in the infrared wavelengths. It has 12 infrared channels, which are used to derive vertical temperature and moisture profiles (soundings) over selectable areas. The concept of obtaining useful atmospheric soundings from geostationary satellites is being tested. VAS sounding data have been used experimentally by the National Meteorological Center (NMC) for initialization of the Limited Fine Mesh (LFM) numerical models, by the National Hurricane Center (NHC) for use in hurricane environment determinations and in the Sanders Barotropic (SANBAR) forecast models, and by the National Severe Storms Forecast Center (NSSFC) to determine parameters used in severe weather forecasting. Results have been encouraging, and efforts are under way to integrate the VAS data into NOAA's operational weather analysis and forecasting programs during the remainder of the 1980's.

VAS data are broadcast by GOES in real time and are received at Federal Building 4 in Suitland, Maryland.* The data are then routed to two processing systems. The first processing system creates digital data for NMC from the imagery. Quantitative products (cloud motion winds, sea surface temperatures, cloud top heights, etc.) are derived from these data. The second processing system, the Central Data Distribution Facility (CDDF), is where the full-disk imagery is formed into selected geographic sectors and distributed via telephone lines to seven Satellite Field Services Stations (SFSS's). The SFSS's are located within NWS forecast offices in Washington, D.C.; Kansas City, Missouri; Miami, Florida; Slidell, Louisiana; San Francisco, California; Anchorage, Alaska; and Honolulu, Hawaii. NWS meteorologists at these field services stations analyze and interpret the data, and assist the NWS forecasters with their regional forecasting responsibilities.

The SFSS's store sequences of images on a video disk system. The sequences are transferred to a TV display, which produces animated motion of the cloud and weather patterns and selected enhancements of the imagery to highlight particular weather features. This animated imagery is extremely useful for interpreting the development, movement, growth, and decay of cloud, storm, and weather systems.

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* In addition to the NOAA VAS receiving station at Suitland, there are 19 other VAS direct broadcast receiving stations in the Western Hemisphere. They are run by foreign governments (Canada, Mexico, France-ESA, Brazil), DOD, NOAA, NASA, universities, and commercial interests.

At each SFSS, communications facilities switch the analog imagery signal at 15- or 30-minute intervals to 56 NWS offices and hundreds of Federal and non-Federal users throughout the United States.

Currently, the SFSS's receive water vapor imagery four times a day. For its Weather Service Forecast Offices (WSFOs), NWS is developing an interactive system to subjectively evaluate satellite imagery and simultaneously compare it with NMC-generated graphic material. This system, the Satellite Weather Information Service (SWIS), can display imagery by NESDIS-produced sector or SWIS-produced subsector. It also has capabilities for animation and conversion of the NMC graphics from AFOS to satellite projection, so that imagery and graphics can be superimposed. SWIS should be in operation at all WSFOs by the late 1980's. The WSFOs will require full-resolution GOES visible, infrared, and water vapor imagery.

<u>NWS Requirements for Derived Digital Data From VAS</u>--The NWS requirements for derived digital data from VAS are as follows:

- Cloud Motion Winds--Using successive images and objective analysis techniques, an automated computer technique derives low-level (below 10,000 feet) winds from the cloud motions over the oceans. These winds are used in NMC numerical weather prediction models. Interactive techniques produce high-level (near 30,000 feet) cloud motion winds. Typically, 1,000 low-level and 300 high- and midlevel wind estimates are derived daily. These cloud motion winds are produced over oceanic areas from 50° N. to 50° S. latitude and from 20° W. to 170° E. longitude. This data set is required by the NWS/NMC four times daily, at 0000 GMT, 0600 GMT, 1200 GMT, and 1800 GMT, at a density of about one data point per 350 km. By agreement with the World Meteorological Organization (WMO), NWS transmits all cloud motion winds to international users on the Global Telecommunications System (GTS).

- Cloud Top Heights--The infrared imagery provides cloud top temperatures. An interactive computer system combines these temperatures with radiosonde data and conventional temperature analyses to assign height values to the cloud tops. These data are required at a minimum of four times daily by the WSFOs, and are used in domestic and international aviation forecasting.

- Quantitative Precipitation Estimates--A combination of manual interpretation and interactive computer enhancement techniques of visible and IR imagery (at 7 km resolution) is used to estimate the amount of precipitation from convective storms and hurricanes. During

significant rainfall or flood events, these estimates are required by the NMC, the River Forecast Centers (RFCs), and the WSFOs hourly to depict cumulative rainfall amounts for areas as small as 50 by 50 km.

- Moisture Analysis--An estimate of the mean atmospheric relative humidity from the surface to 300 mbar at 0000 GMT and 1200 GMT is required by NMC to initialize numerical models of the atmosphere.

- Snow Cover Analysis--The NWS Office of Hydrology (OH) requires 1 km digital visible data biweekly to derive river basin, regional, and national snow cover charts.

NWS Requirements for Imagery and Analog Data From VAS--Current requirements for VAS imagery include:

- Full-disk visible and infrared images every 3 hours, for cloud motion wind vectors used at NMC and NHC

- Partial-disk images (sectors) every 30 minutes, for NWS-wide synoptic and mesoscale system monitoring

- Limited-scan images at 5- to 15-minute intervals for severe storm (at NSSFC) and tropical cyclone (at NHC) monitoring

- Full-disk water vapor images at 6-hour intervals, for midlevel wind vectors and global atmospheric moisture evaluation at NMC

The following interpretive products and services are required from the imagery data:

- Oral Briefings--Oral briefings are provided four times per day to the Quantitative Precipitation, Basic Weather, and Upper Air Branches at NMC. These briefings support the generation of NMC's weather analysis and forecasts.

- Hurricane Classification--The National, East Pacific, and Central Pacific Hurricane Centers use a semiobjective method to classify the stages of development and the maximum winds of tropical cyclones throughout their lifetimes. The locations and tracks of tropical cyclones also are derived from the imagery, and are distributed to NWS forecast offices.

- Satellite Interpretation Messages (SIMs)--The SFSS's produce descriptions of synoptic and mesoscale weather systems as interpreted from the imagery and related NMC guidance. These SIMs are required at least four times

daily by NWS forecast offices, with more frequent updates provided during severe weather.

- Marine Cloud and Weather Analysis--A plain language description of weather conditions over the North Atlantic, Central Pacific, East Pacific, and Gulf of Mexico is required by certain NWS forecast offices four times daily, to assist in marine forecast preparation.

b. GOES Data Collection System (GOES DCS). The GOES DCS is a communication relay system that uses the transponder carried on the GOES spacecraft to relay UHF transmission from Data Collection Platforms (DCPs) to properly equipped ground stations. The primary purpose of the GOES DCS is the collection of meteorological, hydrological, and oceanic data, and a remote calibration of these systems.

As of Feb. 1, 1985, there were 87 organizations managing 4,803 platforms using the DCS system. NOAA has 703 platforms on data buoys, river gauging stations, and remote sites. The Corps of Engineers has 1,540, and the Departments of the Interior and Agriculture have 1,400 and 223 platforms, respectively. Other Federal users account for 110 more. The remaining platforms are operated by various foreign, academic, or other entities, cooperatively or under the sponsorship of U.S. agencies.

A potentially important use of satellite communications is the timely relay of accurate high-altitude weather parameter reports from aircraft specially equipped with a device known as the Aircraft to Satellite Data Relay (ASDAR). This system was developed during the First GARP Global Experiment (FGGE), and it shows good potential to increase the quantity of high-level observational data, particularly over the oceans. The ASDAR processes the parameters (temperature and wind) sensed by the aircraft's instruments for relay via GOES satellite to analysis centers such as NMC. Aircraft reports are a reliable and important data source for global analyses and forecast model inputs, but they are not always received in a timely manner under current communications methods. ASDAR offers a way to provide timely data. Aircraft from WMO members will be equipped with ASDARs; plans are for 65 to 85 ASDARs to be in operation by 1990. In addition to temperature and wind reports, turbulence and maximum-wind data reporting capabilities are planned.

Similarly, the number of data buoys also is expected to increase during this period. Provision must be made for an increased capacity to relay these kinds of information.

Requirements for the Acquisition of Data From the GOES DCS-- NWS uses hydrometeorological data from about 75 percent of the

4,803 DCPs in river-stage and flood forecasting; the DCPs also provide information for site maintenance. The platforms routinely provide reports every 1 to 6 hours, depending on location and need. Special observations are made more frequently, when needed. All these data are made available to users within 10 minutes of observation time.

Many DCPs are at unattended or nearly inaccessible locations. They are often the only source of ground-based data in these areas. NWS has come to rely on DCP data in preparing flood warnings and forecasts, and expects that it will continue to need at least as much data as are available currently.

The most reliable data from ocean areas are communicated via the DCS on the GOES satellite. DCPs located on data buoys, offshore platforms, and tsunami-reporting tide gauges provide data on a scheduled time basis and on an event-triggered threshold. These platforms also are capable of being interrogated through the DCS, particularly during severe events such as tsunamic earthquakes, hurricanes, and storm surge. The NWS forecasters will continue to depend on this type of information to issue warnings and advisories. Data types and reporting intervals vary widely, as shown in Table III-1.

c. Weather Facsimile (WEFAX) Service. Under the auspices of the WMO, the United States has had a long-standing responsibility to provide for dissemination of meteorological data to the international user community. One important way to fulfill this responsibility is the WEFAX service, an S-band broadcast of processed satellite images, National Weather Service meteorological charts, and alphanumeric products. These products are sent at scheduled times, via the geostationary U.S. satellites, from the NOAA Command and Data Acquisition Station in Virginia.

In the Western Hemisphere, WEFAX broadcasts are acquired at approximately 160 locations, of which 57 are operated by foreign governments and 23 are operated by the U.S. Government. The remainder are academic, commercial, and amateur stations. More WEFAX stations probably will be established in the future.

In an effort to reduce communications costs, NWS has substantially increased the number of weather charts sent by WEFAX. This also benefits many foreign governments, and is part of the NWS policy of supplying and exchanging data to accomplish NOAA's operational mission and to satisfy the U.S. commitments to the WMO. NWS expects to continue these activities in the future.

At present, about 42 percent of the WEFAX transmissions are

Table III-1
Current DCP Requirements

Data Type	Routine Report Interval	Special Report Interval	Interrogate
Precipitation	6 hourly	15 min to hourly	--
River stage	6 hourly	hourly	--
Lake elevation	6 hourly	hourly	--
Water temperature	daily	6 hourly	--
Snow water equivalent	daily	6 hourly	--
Air temperature	6 hourly	--	--
Dew point temperature	6 hourly	--	--
Pan water temperature	6 hourly	--	--
Soil temperature	daily	--	--
Humidity	daily	6 hourly	--
Wind velocity (hydrology)	daily	6 hourly	--
Battery voltage	daily	--	--
SST	daily	6 hourly	--
Atmospheric pressure	3 hourly	15 min to hourly	yes
Wave height	6 hourly	hourly	yes
Wind velocity (marine)	3 hourly	15 min to hourly	yes

GOES imagery, most of which are gridded; 20 percent are mapped polar orbiter Advanced Very High Resolution Radiometer (AVHRR) imagery; 35 percent are NWS meteorological charts; and the remaining 3 percent are scheduling charts and other operational data. NOAA does not operate WEFAX receiving stations, but it uses the WEFAX system to broadcast meteorological charts to users, especially in remote areas. NWS supports WEFAX as an inexpensive mode of disseminating weather charts to the international meteorological community.

d. <u>NWS Requirements for Future (Beyond 1990) Geostationary Satellites (GOES-Next)</u>. The NWS emphasis during the 1990's will be on improving warnings and short-term (0 to 12-hour) forecasts of severe weather events such as tornadoes, severe thunderstorms, hail, and flash floods. NWS expects that GOES-Next satellites will provide strong support to this effort. Larger scale weather forecasting also is expected to benefit from improvements in imagery and vertical temperature/moisture sounding capabilities. The following information summarizes NOAA's GOES-Next requirements. (For more detailed information, see "NWS GOES-Next Requirements," April 1, 1983.)

NWS expects that GOES-Next imagery data must be acquired and distributed in five channels, including the visible (0.55-0.75 μm) and split-window infrared (10.2-11.2 μm and 11.5-12.5 μm). These channels will be used for storm detection, low-level water vapor detection, precipitation-rate estimates, and cloud tracking. In addition, two more multispectral channels will be carried by GOES-Next: the 3.8-4.0 μm channel, for improved cloud detection at night and water vapor estimation, and the 6.5-7.0 μm channel, for midlevel water vapor detection and cloud tracking. Images will be over the United States and will be distributed in 5-, 15-, or 30-minute cycles. Spatial resolution will range from 1 km for visible imagery to 4 km for the infrared channels, and to 8 km for the midtropospheric water vapor (6.5-7.0 μm) channels. The satellite imagery will be navigated accurately in both a relative (picture-to-picture) and an absolute (picture-to-ground) sense to facilitate its use with high-resolution radar imagery and other data.

Further, NWS expects that sounding capabilities will include the acquisition of abbreviated profiles of temperature and humidity at 25 to 30 km resolution over the U.S. on a half-hourly basis for mesoscale forecasting, and more comprehensive temperature/humidity profiles from the surface to the tropopause within one-half hour of observation time twice a day for numerical guidance models. These sounding requirements must be met without disrupting the acquisition of imagery. Tables III-2 and III-3 present NWS's requirements.

Table III-2
GOES Imagery Requirements

Channel	Potential Uses	Spatial Resolution (in km.) at nadir	Brightness/ Thermal Resolution	Time Resolution	Delivery Time to Ground Processing System
0.55-0.75 μm/visible	Cloud mapping/typing, storm detection, cloud motion, winds, snow	1	S/N=1.5:1 at 0.5% albedo	U.S. sector; 5-15 min repeat for U.S. and coastal water coverage (Minimal conflict with full disk imagery, see text) Full disk Time consistency 3 images at ½ hourly intervals repeated 4 times a day	Near instantaneous, (less than 30 sec)
3.8-4.0	Cloud detection (night, H_2O vapor estimates) [fire detection, night cloud motions, winds, and navigation (2 km resolution*)]	4	NE ΔT 1.4 K at 300 K		
6.5-7.0	Midtroposphere water vapor jetstream ident., cloud type, sea surface temperature	8	NE ΔT 1.0 K at 230 K		
10.2-11.2	Cloud mapping/typing, storm detection, motions, winds, surface temp., soil moisture, precipitation estimates	4	NE ΔT 1.4 K at 200 K		
11.5-12.5	Low level H_2O vapor, sea surface temperature	4	NE ΔT 0.35 K at 300 K		

* Possible future requirement

Table III-3
GOES Sounding Requirements

Potential Uses	Geographic Coverage	Instrument Spatial Resolution	Time Resolution	Accuracy*		
Local mesoscale forecasting (Stability indexes tropospheric circulation features, moisture trends in lower troposphere)	3000x3000 km area relocatable**	(FOV at NADIR)	$\leq$ 30 min	Temperature (°C)		
				Layer	Minimum	Desirable
				1000-700mb	2.0	1.5
		Minimum		700-300mb	1.5	1.0
				300- 50mb	2.5	1.0
Numerical modeling		15x15 km				
				Relative humidity		
		Desirable				
Backup for polar sounding				Layer	Minimum	Desirable
		10x10 km				
				1000-700mb	20%	15%
Hurricane prediction				700-300mb	15%	10%
				300- 50mb	15%	10%

* Accuracy is defined in a cloud-free area per 100mb-thick layers.

** This area will usually be over the U.S. but on demand can be changed to other areas. The horizontal density of temperature and moisture retrievals will be a function of the ground processing equipment.

2. Operational NWS Requirements for Polar-Orbiting Satellite Products and Services

The NOAA Polar-orbiting Operational Environmental Satellites (POES) are designed to provide the quantitative data required for improved NWS numerical weather prediction models. These spacecraft carry instruments that supply temperature soundings; microwave channels are included to facilitate sounding retrieval in cloudy areas. They also provide multichannel image data, and carry a data collection and platform location system. The principal requirements for polar-orbiter satellite data are to:

- Provide vertical temperature and water vapor profiles (soundings) in the troposphere, and temperature profiles in the stratosphere
- Provide multispectral imagery and radiance data at spatial resolutions of from 1-4 km
- Provide imagery distribution to users in near-real time
- Collect and relay environmental data from instrumented platforms to a central site for delivery to platform owners/operators

Provision should be made for an alternate means to acquire polar-orbiting satellite data in the event of a NOAA satellite failure. The DOD's DMSP should be examined as a possible alternate.

The principal sensing capabilities used by NWS and carried on NOAA's polar-orbiting satellites include the TIROS Operational Vertical Sounder (TOVS), the AVHRR, and the DCS. Major communication capabilities that support these systems are the High Resolution Picture Transmission System (HRPT) and the Direct Sounder Broadcast (DSB) system.

a. <u>TIROS Operational Vertical Sounder (TOVS).</u> The TOVS system consists of a High Resolution Infrared Radiation Sounder (HIRS/2), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU). The primary instrument for tropospheric data, HIRS/2, provides data for the calculation of vertical temperature profiles, water vapor content at three levels of the atmosphere, and total ozone content. The SSU instrument provides temperature information in the stratosphere. The MSU is used in conjunction with the HIRS/2 instrument to enable atmospheric sounding computations to be made in the presence of clouds.

A variety of computer and analytical products is required by NWS and also is distributed to other users over various

national and international telecommunications links. NWS requirements for TOVS derived products include:

- Mean temperatures for 40 atmospheric layers from the surface to 0.40 mbar and precipitable water amounts for three layers of the atmosphere: surface to 700 mbar, 700 to 500 mbar, and above 500 mbar. TOVS soundings are required at a spatial resolution of 250 km, and they must be delivered to NMC for use in numerical models by 0000 GMT and 1200 GMT. They are transmitted to international users via the Global Telecommunications System (GTS). These data play a crucial role in the production of national and global numerical guidance products.

- Approximately 600 sounding retrievals per orbit; the two polar-orbiting satellites provide 16,000 global soundings per day for global models.

b. Advanced Very High Resolution Radiometer (AVHRR). The AVHRR provides multispectral (visible, near-infrared, and infrared) imagery and quantitative radiance data for forecasting purposes in a variety of ways. High-resolution (1 km) data are broadcast in real time via the High Resolution Picture Transmission (HRPT) system. The high-resolution data from Local Area Coverage (LAC) are recorded on onboard satellite tape recorders. All AVHRR data are processed and stored (at 4 km resolution) on board the satellite for Global Area Coverage (GAC). The LAC and GAC data are played back and transmitted when the satellite is within view of a NOAA ground station. The low-resolution data from two channels are also broadcast in real time in an analog facsimile format via the Automatic Picture Transmission (APT) system.

NWS Requirements for Derived Digital Products From AVHRR--Sea surface temperature (SST) analyses are used for locating thermal boundaries, analyzing and forecasting sea fog, and locating major current boundaries (Gulf Stream, equatorial counter currents, etc.). Between 20,000 and 40,000 observations of sea surface temperature are produced each day from two satellites. The number of observations varies with cloud cover. SST observations are required at 25 km resolution for global applications and at 8 km for U.S. coastal region applications.

NWS Requirements for Derived Analog or Imagery Products From AVHRR

- Global cloud maps, both visible (day) and infrared (day and night), are required by NMC to prepare global analyses of weather patterns. The GAC data are required in near-real time, as data from an Earth orbit are being

processed. Imagery sectors are required by international users, and are sent via National Weather Service facsimile circuits and the WEFAX communications system on the GOES satellite.

- The U.S. Navy/NOAA Joint Ice Center (JIC) in Suitland, Maryland, requires the high-resolution visible and infrared images for analyzing ice conditions over ocean areas and the Great Lakes.

- Visible imagery data are required by the NWS Office of Hydrology, in support of the NWS flood forecasting programs, to produce snow cover maps used for estimating snow pack in watersheds and predicting spring melt.

- The NWS/NMC Climatic Analysis Center (CAC) requires satellite-derived sea surface conditions analyses (imagery and sea surface temperature) for monitoring ocean conditions and for analysis and forecasting of climatic abnormalities (e.g., the 1982-83 El Niño), and their potential effects.

- Measurements of daytime and nighttime outgoing longwave flux and incoming available and absorbed solar radiation, using infrared and visible radiances averaged for 50 km regions, are required. Radiation budget measurements must be mapped into 2.5 degree latitude/longitude fields (250 km resolution) and stored on a monthly archive file. The satellite-derived global radiation budget fields are required by NWS for long-range forecasting and climate monitoring and research.

- The WSFOs in Alaska require high-resolution polar-orbiting imagery for their warning and forecast programs. At high latitudes in the Northern Hemisphere, it is possible to obtain such imagery every 90 minutes. The lack of surface reporting stations in the Arctic makes these satellite data important sources of weather information.

c. Data Transmission Capabilities--APT, HRPT, and DSB. In addition to the satellite transmission capabilities needed by NESDIS to command the satellite, monitor the condition of the onboard systems, and transmit data to NESDIS facilities for central processing, three communication systems are used: APT, HRPT, and DSB.

Automatic Picture Transmission (APT)--Low-resolution data from two channels (visible and infrared) of the AVHRR are broadcast in real time via APT, principally to users in other countries. This service is part of NOAA's long-time international commitment to provide satellite data.

High Resolution Picture Transmission (HRPT)--The NOAA polar-orbiting satellites carry three S-band transmitters. Two transmitters are required to send data to NOAA's Command and Data Acquisition (CDA) stations in Alaska and Virginia. The third provides redundancy and also serves as the HRPT transmitter, which constantly broadcasts the high-resolution AVHRR data to any ground station equipped to receive the signals. NWS requires the acquisition and delivery of AVHRR data both directly at WSFO San Francisco and indirectly through the GOES-Tap system.

Direct Sounder Broadcast (DSB)--DSB services are derived from the operation of the TOVS instruments flown on TIROS-N series polar-orbiting spacecraft. Data from the current instruments (MSU, SSU, and HIRS/2), when processed on the ground, provide a detailed profile of atmospheric temperature and humidity. Direct Sounder Broadcast enables other countries to access satellite data when the satellite is directly overhead. The receipt of DSB data requires the use of sophisticated and costly systems and processing techniques. Although the number of sites receiving these data is expected to increase, that increase will be slow.

Analysis of TOVS data requires very sophisticated computer processing. To date, only eight countries (Australia, Canada, the Federal Republic of Germany, France, Poland, the U.K., the U.S., and the U.S.S.R.) have developed facilities to analyze TIROS vertical sounding data adequately, and all are operated by government meteorological services.

d. NWS Requirements for Future (Through 1995) Polar-Orbiter Satellites (NOAA K, L, and M). While NWS will be emphasizing improvements in small-scale forecasting through the 1990's, it will maintain its historic focus on the area of synoptic-scale forecasting. The NOAA polar-orbiting satellites have become reliable suppliers of high-quality data to numerical weather prediction models, and future satellites will concentrate on supplying data to improve forecast models. NOAA K, L, and M will satisfy NWS requirements for polar orbiter data through 1995. Further work will be necessary to define the requirements through the year 2000. The NWS requirements for improved satellite input to the models are:

- Better accuracy of temperature data, especially in cloudy areas
- Better horizontal and vertical sounding resolution
- More information on atmospheric moisture (water content, precipitable water)

- More timely delivery of observations

In addition, NWS will have continued satellite requirements for communications and special programs. The NOAA K, L, and M polar orbiters, the first of which will be available for launch in March 1990, will have infrared sounders (HIRS/2) with the same temperature accuracy as current ones (2.0 K). The improvement of the NOAA K, L, and M TOVS system results from the Advanced Microwave Sounding Unit (AMSU), which will provide soundings in cloud-covered areas with an accuracy comparable to the HIRS/2. The AMSU also will improve the vertical sounding resolution compared to the current sensors (MSU and SSU), which it will replace. The AMSU will contain 20 channels, as follows:

- Twelve channels, with about 40 km horizontal resolution in the 50.3-58 GHz oxygen absorption band, that yield temperature weighting functions with peak heights (near nadir) nearly equally spaced from 0-42 km.

- Three channels, at 23.8, 31.4, and 89 GHz, that sense: 1) tropospheric water vapor; 2) precipitation in emission over the oceans, together with 3) sea-ice type and ice coverage; 4) and other parameters, such as snow cover and ocean wind stress. Horizontal resolution is to be of 40 km.

- Five channels, with 15 km resolution at 89 GHz, 166 GHz, and 3 frequencies centered at the strong 183 GHz water vapor resource, that sense water vapor profiles and precipitation over land and sea, and are particularly sensitive to convective cells with ice crystals aloft.

The current TOVS infrared channels provide vertical temperature resolution of about 10 km to a height of 42 km. Such resolution is necessary for global temperature and geopotential analyses; data below 30 km are used for medium-range numerical weather prediction, with data above 30 km used to monitor climatic change. The AMSU will improve, by a factor of about 1.7, vertical resolution below 35 km, with greater swath width; reduced accuracy will be possible to 45 km. Polar satellites are as important in relaying global data from other observing systems to NWS as they are in producing sensor data. Drifting buoys are expected to play an increasing role on the global scale into the 1990's, as one data source that will improve the World Weather Watch Global Observing System.

Data from drifting buoys require relay by polar-orbiting satellites in near-real time; these data are important in improving the monitoring and forecasting of marine weather, particularly in producing warnings and forecasts for hurricanes and coastal storms. In addition, the polar-orbiting satellites will be

able to receive, process, and retransmit data from other observation platforms worldwide, such as free-floating balloons, moored buoys, and remote automatic observing stations, and will be capable of tracking platforms in motion. DSB, AVHRR, APT, and HRPT capabilities, or their equivalents, will be provided that have characteristics at least identical to those of the current satellites.

Other NWS programs served by the AMSU will include sea-ice monitoring and forecasting. Three channels (31.4 GHz, 89.0 GHz, and 166.0 GHz) will provide data at 50 km horizontal resolution, with an accuracy of 10 percent in location.

e. NWS Requirements for Other Future Polar-Orbiting Satellites/Platforms. NASA research and development spacecraft programs (e.g., Nimbus, Seasat) have shown that satellite observations can play an important role in providing data for both the operational analysis of, and research on, oceanic conditions. Building on that satellite heritage, the National Oceanic Satellite System (NOSS) was proposed as a limited operational demonstration to test the feasibility of obtaining microwave spectral interval measurements of surface wind velocity, sea surface temperature, significant wave height, sea ice conditions, current measurements, chlorophyll concentration, and other optical characteristics from a polar-orbiting satellite. Because of the ability of microwave sensors to effect surface observation during cloudy conditions, microwave data are expected to improve significantly the efficiency, safety, and effectiveness of marine transportation, offshore exploration, platform operations, construction, and scientific knowledge of ocean surface dynamics.

Several of these sensors have now been flown in space, and it has been demonstrated that they can be used as a part of the operational warning and forecast program of NWS. As a result, there is a requirement for an operational polar-orbiting satellite/platform system that can provide information on the characteristics of the ocean surface.

3. Research Requirements

Hydrometeorological, oceanic, and NWS research applications of satellite data cover a wide range of NWS activities. Emphasizing multiple uses of image and digital data, applied research is aimed at a better understanding of atmospheric and oceanic processes and improving NWS services. Satellite image data are essential for case studies of severe storms, flash floods, and hurricanes. Specific digital parameters from satellite sounding systems, such as wind direction and speed and temperature profiles, support forecast modeling research. Studies to improve measurement of ocean currents, ice, and sea surface temperatures are vital to routine weather prediction, the

analysis of air-sea interaction, and ongoing climate change.

Over the next 15 years, NWS will need increased access to digital and infrared image data and rapid-scan data, improved time-sequence imagery, increased resolution of the geostationary infrared image data to 4 km, and access to ocean satellite data and derived products. These data are required for developing and testing interactive small-scale warning and forecast techniques and procedures. These techniques and procedures would be transferred from research organizations to the operational components of NWS.

The use of operational environmental satellites to carry research instruments, which provide research data, and/or collection and data relay capabilities has proven to be cost effective and is a basic requirement for successful research. Flight testing of prototypes for future operational instruments is essential for ensuring trouble-free operation in the future.

a. NWS Meteorological Satellite Research Program. Meteorological research on small-scale processes during the next decade will require access to high-frequency (5- to 15-minute) satellite data on request. Such requests, in most cases, will be related to meteorological conditions that are precursors to or associated with the development of severe convective storms, tornadoes, hurricanes, flash floods, and heavy snowfall. The 13 channels on the VAS will provide detailed information of importance to operational forecasters throughout the NWS. More specific details may be found in the reference document entitled "Program Development Plan: Improving NOAA Weather Services Through More Effective Use of GOES Remote Sensing Capabilities," November 1982.

Current VAS satellite operations will continue to provide 5- to 30-minute multispectral imaging, hourly soundings, direct readout capabilities, navigational parameters, and digital data bases in support of applied hydrometeorological research activities.

Specific projects that will be developed in conjunction with research components throughout NOAA and have a high assurance of coming to fruition within the ENVIROSAT-2000 period are described in the following sections.

Joint Profiler-VAS Evaluations--Joint satellite/Profiler soundings are under active study to improve the measurement of atmospheric variables from satellites, especially in the lower altitudes of the atmosphere. The Profiler acts as a benchmark providing accurate absolute values in joint profiling. The concept now being studied envisions realistic spatial extrapolations of joint profiling products, since the satellite

sounder can measure the horizontal gradients of the temperature and humidity between Profiler stations. This work is expected to lead to operational mesoscale forecasts and forecast models, and improved synoptic-scale satellite observations of temperature and humidity. Present and future research needs for NOAA satellite products include all thermal soundings for the continental U.S. and nearby oceanic areas, and all present and future polar orbiter sounding products.

Mesoscale Analysis and Modeling--Studies to integrate Profiler, NEXRAD, and other data sources, and to apply them to mesoscale events and studies of atmospheric dynamics, require full resolution VAS and polar orbiter sounding data sets. Also, VAS imaging products and derived polar orbiter sea surface temperature products are required.

VISSR Atmospheric Sounder (VAS)--NWS requires continued assessment and development of VAS data and products during the period 1985-87. VAS data delivery is required as follows:

- Dwell soundings (a VAS-specific term) are being evaluated at NMC and NHC for use in operational numerical weather analysis and forecast models. Vertical temperature and moisture profiles derived over oceanic areas and VAS-derived fields will be entered into the models and evaluated with respect to their effect on both analyses and forecasts.

- Multispectral imagery from the VAS instrument will provide, at hourly intervals, measurements of thermodynamic stability and atmospheric humidity over selected areas of the United States. Derived stability indices and potential thickness values will be used interactively and evaluated at the National Severe Storms Forecast Center (NSSFC) for forecasting the outbreak of severe convective storms.

- Individual imagery channels, such as the 6.7 m water vapor channel, and composite imagery will be evaluated for their utility in depicting atmospheric moisture fields and subsequently improving analysis and forecast techniques for severe storm outbreaks and hurricane movement. Composite imagery is being evaluated routinely at NSSFC, and water vapor imagery is evaluated at all national centers and WSFOs.

Program for Regional Observing and Forecasting Services (PROFS)--The Program for Regional Observing and Forecasting Services requires satellite data to support requirements and design efforts for an interactive system (AWIPS-90) design prototype. PROFS requirements for satellite data are shown in Table III-4.

Table III-4
PROFS Satellite Data Requirements

Product	Domain	Frequency	Map Base	Resolution	Delay
Visible image	Cont. U.S.	5 min	Lambert	1 km	1 min
Infrared images (4 VAS channels)	Cont. U.S.	5 min	Lambert	2 km	1 min
VAS soundings	Cont. U.S.	1 hour	NA	10 km	10 min
Infrared images (2 VAS channels)	N. America (LFM)	1 hour	Polar stereographic	10 km	

Note: Navigation should be 1 km RMS for all products.

b. NWS Oceanographic Satellite Research Needs. The need for timely and accurate measurements of the marine environment has increased dramatically during the past decade. Analyses and prediction of oceanic and coastal conditions are essential for supporting rapidly increasing maritime activities. The availability of satellite data is of primary importance for improvements in derived ocean surface information from both polar-orbiting and geostationary satellites.

Future oceanic satellites equipped with various sensors will provide a myriad of parameters needed by NWS. The sensors on these satellites will be both active and passive, and will include:

- Scatterometers that will provide global sea surface wind fields and wave height information. This will enable scientists to study waves, wind driven ocean circulation, and interaction between the oceans and atmosphere.

- Altimeters that measure sea surface topography will provide information on ocean currents and waves. The altimeters also will be used for determining ice sheet heights and ice boundaries.

- Ocean Color Instruments that will monitor chlorophyll concentration. This information could be used by NWS to aid in the detection of water masses and eddies.

- Radiometers that will provide all-weather global sea surface temperatures, ice age, rainfall rates, wind speed, and atmospheric water vapor content.

- Synthetic aperture radars that can resolve ice boundaries to the order of tens of meters. These high-resolution ice data can determine individual ice floes and their motions, which can impact navigation and mineral exploration.

The data derived from these instruments should help in research to improve the efficiency, safety, and effectiveness of marine transportation, offshore exploration, construction, and scientific knowledge of ocean surface dynamics. A partial listing of derived parameters for oceanic climate research and prediction is given in Table III-5.

c. Hydrological Research Program. The NWS Office of Hydrology (OH) requires weekly imagery for depictions of snow coverage, water equivalence, soil moisture, plant vegetation moisture, and wet areas at 50 km resolution. OH also requires quantitative satellite-derived estimates of precipitation for radar research projects at a spatial resolution of 2-4 km at half-hourly intervals.

Table III-5
Summary of NWS Ocean Climate Requirements

Parameter	Usefulness	Estimated Accuracy	Approximate Horizontal Resolution	Approximate Temporal Resolution
Sea surface temperature	Measure of thermal energy of transfer from ocean to atmosphere	1 °C (satellite)	25 km (global) 8 km (U.S. coastal)	3 days
Wind stress	Relationship to ocean currents, which transport heat energy poleward; wave generation	0.2 dyn cm^{-2}	200 km	5 days
Sea level (dynamic topography)	Climatic current fluctuations; changes in heat content and sea level	2 cm	50 km	1 week
Surface currents	Oceanic heat transport; energy distribution	2 cm sec^{-1}	Critical areas only	1 month
Sea ice extent	Atmospheric energy; mass and heat exchange between ocean and atmosphere	2%	50 km	3 days
Salinity	Determination of freezing point of sea water; ocean density and circulation; global precipitation	0.01 ppt	200 km	1 month

Other operational quantitative measurements include:

- Areas of flood inundation at 50 km resolution for selected river basins weekly
- Frozen ground areas at 2 km resolution weekly
- Forest-fire-burned areas at 50 km resolution within 2 days of a fire

d. Long-Range Research Potential. Certain programs and activities currently initiated or developing that have a long lead time may affect NWS needs during the ENVIROSAT-2000 period. These activities will likely extend into the next century. They include Windsat, satellite-borne radars, the Lightning Mapper, and the possibility of geostationary microwave sensors, which offer potential for improved observations or products.

Windsat--An example of possible future NWS needs includes a concept known as the wind satellite (Windsat). This concept, developed in the mid-1970's, is designed to measure global winds using IR Doppler lidar mounted on a polar-orbiting satellite, which would provide twice-daily input for NMC numerical guidance and would obtain a truer measure of atmospheric dynamics.

The Windsat concept uses aerosol backscatter from lidar to obtain profiles of wind speed, which are (theoretically, at least) better indications of atmospheric dynamic conditions than are temperature profiles. These wind profiles also are held to be superior to present-day winds derived from cloud motions (which are limited in height and geographic distribution) and temperature soundings in the tropics. Data from ground-based and airborne lidars are being evaluated as part of a plan for a global backscatter assessment. Cost considerations make testing of a satellite-borne lidar unlikely before the year 2000, but prototypes may need to be evaluated within the ENVIROSAT-2000 period.

Satellite-Borne Radars--Space-borne radar is regarded as an extension of the ground-based radar system for measuring rainfall rates over land areas; it also would be the only source of this information over the oceans. Research studies at the present time envision an airborne meteorological radar, modified to find the minimum detectable rain rates by path attenuation rather than reflectivity, to be used in designing a satellite-borne sensor. Preliminary results show that this method works best directly beneath the aircraft subpoint track, but there is the potential for further refinement.

In conjunction with these studies, a ground-based radar at

Wallops Island, Virginia, is being modified to permit measurement of rainfall rate based on differential reflectivity, which will help serve as ground truth for airborne (and later satellite-borne) radars. NWS has a requirement for improving rainfall rate data via satellite sensors, and NESDIS should continue to monitor developments in that area.

Space-Based Lightning Detectors--NWS is evaluating the usefulness of lightning detection mapping systems. Current research using experimental ground- and aircraft-based sensors has suggested several potential uses of lightning mapping in severe storm monitoring and warning. A satellite-based lightning detector would be able to cover ocean areas to enhance marine and aviation warning and forecast services, and it could augment (but not replace) a projected operational network of ground-based sensors.

Lightning monitoring could be done on a large scale, permitting evaluation, for research and operations, of the relationship of lightning to storm development, growth rates, precipitation, and wind fields. Present optical technology appears to allow detection of lightning from geosynchronous altitudes during daylight and darkness over nearly the full disk, with a spatial resolution of 10 by 10 km and a time resolution of 1 ms. Should such a space-based system be both accurate and cost effective, GOES-Next might supply the vehicle to provide such information; however, further examination of space-based lightning detection feasibililty and cost effectiveness is required.

Geostationary Microwave Sounding Sensor--Despite the substantial improvements expected with the GOES-Next sensors, the problem of taking accurate sounding observations in cloudy areas will most certainly remain. NWS recognizes this problem as technologically and financially based. Every effort should be made to remain aware and capitalize on potential breakthroughs.

4. International Requirements

Meteorology and oceanography represent two of the few sciences in which cooperation on a global scale is a necessity rather than an option. The provision of observations around the globe aids in specification of the atmosphere for prediction purposes. Without these observations, trade and commerce periodically would be subjected to unacceptable losses much like those experienced by shipping operations a century ago. In a wide variety of ways, these losses and inefficiencies would translate into higher costs for goods either imported or produced in the U.S.

Environmental satellites play an increasingly important role

in the provision of a large observational data base covering oceanic areas. Included in that data base are imagery (visible, IR, and water vapor channels) and soundings. As in the U.S., the imagery is used in many different subjective ways, including the provision of marine, agricultural, and public services. Soundings are utilized by a few developed countries to specify initial conditions for global and regional models. This trend is not expected to abate.

The World Meteorological Center's demand for sounding data may easily outstrip the ability to provide it at reasonable cost. Although numerical modelers have talked about having satellite soundings over data-sparse ocean areas as frequently as eight times per day and at resolutions of 10 km, a more realistic summary of overall global observational requirements (space-based and ground-based) has been developed by the Working Group on the Global Observing System (GOS) of the Commission for Basic Systems (CBS) of the WMO. These results are summarized in Table III-6 and represent a trend of global observing needs.

A second category of requirements centers about the need to provide increased DCP capacity for observing systems such as ASDAR, the Automated Shipboard Aerological Programme (ASAP), the Shipboard Environmental (Data) Acquisition System (SEAS), and data buoys. There is no question of the growth of these programs, but channel capacity or new technological approaches for satellite communications should be explored.

Satellite requirements currently are being formulated for the AWIPS-90 program. It is expected that data from the Geostationary Meteorological Satellite (GMS), Meteosat, and polar satellites will be required for NWS programs such as hurricane forecasting and the issuance of marine and international aviation advisories.

5. <u>Composite Satellite Data Requirements</u>

Composite satellite data requirements of NWS are shown in Table III-7.

Table III-6
Basic Set of Global Observational Data Requirements to be Met by the GOS by the Year 2000
(Desirable GDPS goals for hemispheric and global models are given in brackets)

	Horizontal Resolution	Vertical Resolution	Observational Error (rms)	Frequency of Observation
I. Upper-air temperature (T)	250 km *	10 layers in troposphere 5 layers in stratosphere	0.5-1 °C troposphere 1-2 °C stratosphere	2-4 per day
	[100 km]	[500 m-2 km] [1 km-15 km] [3 km-30 km]		[4 per day]
II. Upper-air wind vector (V)	250 km *	10 layers in troposphere 5 layers in stratosphere	1-2 m s^{-1} troposphere 2-3 m s^{-1} stratosphere	2-4 per day
	[100 km]	[500 m-2 km] [1 km-15 km] [3 km-30 km]		[4 per day]
III. Upper-air relative humidity (RH)	250 km	4 layers	30% - but better near surface	2-4 per day
	[100 km]	[5 layers]	[10%]	[4 per day]
IV. Sea surface temperature(T_s)	250 km	---	0.5 °C with systematic differences among observing systems eliminated on 3-day averages	Instantaneous measurements averaged over 3 days
	[100 km in areas of boundary currents, upwelling, and near the Equator]			

Note: This table defines a basic set of the global observational data requirements that generally can be met by the GOS-2000 and, therefore, should be used in the design and implementation of the GOS.

* Tropics, 500 km resolution sufficient for temperature.

Table III-6 (concluded)
Basic Set of Global Observational Data Requirements to be Met by the GOS by the Year 2000

	Horizontal Resolution	Vertical Resolution	Observational Error (rms)	Frequency of Observation
V. Surface pressure (P) temp. (T,Td) wind vector (V)	250 km	—	0.2% pressure 0.5 °C temperature 1-2 m s^{-1}	4 per day
	[100 km]		[0.1% pressure]	[8 per day, particularly where spatial requirement not met]
State of surface and soil	**	**	**	**
	[100 km surface 300 km subsurface]	—	[1 °C soil temp.]	[1 per day]
VI. Satellite imagery***	At least 3 km horizontal resolution of imagery	At least 3 layers — low, middle, and high — cloud top height	To be determined; will be a function of latitude for geostationary satellites	8 per day

** Includes precipitation, soil moisture, soil temperature, emissivity, albedo, and snow and ice coverage. Resolution, accuracy, and frequency not yet determined; information required from other Commissions.

*** Satellite imagery included here because of its use in computing vertical motion and divergence fields, and for determining synoptic distribution of water vapor, precipitable water, and cloudiness.

Table III-7
NWS Composite Data Requirements (1985–2000)

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)
Cloud motion winds high level low level	 m/sec m/sec	 7 m/sec 2 m/sec	 — —	 150–400 mb 800–900 mb	350	6	1.5	50 N.–50 S. 20 W.–170 E. (except Conus)	— —
Cloud top heights	mb	50 mb	—	Sfc–100 mb	100	Hourly	—	Conus	—
Precipitable water (image)	cm	30%	—	0.4–1000 mb	7	Hourly	5 min	Conus	—
Relative humidity (image)	percent	Better than 30%	—	0.4–1000 mb	7	Hourly	5 min	Conus	—
Snow cover	km^2	15 km^2	—	$2x10^6$ km^2 – $20x10^6$ km^2	2	Biweekly	—	N. Amer.	—
Stability indexes (image)	total/totals lifted index	20%	—	—	7	Hourly	5 min	Conus	—
Quantitative precipitation estimates	in	20%	—	—	50	Hourly	5 min	Conus	—
Moisture profiles	g/cm^3	Better than 30%	—	—	10–50 150–250	6	—	Regional Global	—
Water vapor winds	m/sec	5-10	—	400–700	350	6	1.5	50 N.–50 S. 20 W.–170 E. (except Conus)	—
Full Earth disk image Vis and IR	—	—	—	—	Vis 1 IR 4	3	—	Hemispheric	—
Partial disk image Vis and IR	—	—	—	—	Vis 1 IR 4	15-30 min	—	3/4 of full disk	—
Limited scan images	—	—	—	—	Vis 1 IR 4	5 min	—	Conus	—

Table III-7 (continued)
NWS Composite Data Requirements (1985-2000)

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)
Full disk images in the water vapor portion of the IR	--	--	--	--	8	Hourly	--	Hemispheric	--
Layer mean temp. profiles (GOES)	K	2.5	--	Sfc-150 mb	50	3	--	Conus	--
Layer mean temp. profiles (polar)	K	1000-500 mb 2 K 500-700 mb 1 K	--	Sfc-0.4 mb	50-250	2-4 times per day	--	Regional Global	-- --
Net radiation	W/m²	20 W/m²	--		50	Daily	--	Global	2.5 lat./long.
Albedo	percent	.005	--		50	Daily	--	Global	2.5 lat./long.
Daytime outgoing longwave radiation	W/m²	±5 W/m²	--		50	Daily	--	Global	2.5 lat./long.
Nighttime outgoing longwave radiation	W/m²	±5 W/m²	--		50	Daily		Global	2.5 lat./long.
Daily average outgoing longwave radiation	W/m²	±5 W/m²	--		50	Daily		Global	2.5 lat./long.
Available solar energy	W/m²	±10 W/m²	--		50	Daily		Global	2.5 lat./long.
Absorbed solar radiation	W/m²	±10 W/m²	--		50	Daily		Global	2.5 lat./long.

Table III-7 (concluded)
NWS Composite Data Requirements (1985-2000)

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)
Sea surface temp. (SST)	°C	2 °C 1 °C	0.5	-2 °C to 35 °C	25 8	3		Global U.S. coastal region	
Snow cover	km^2	50 km^2	4 km^2	2×10^6 km^2 - 50×10^6 km^2	4	Weekly		N. Hemis.	
Wind stress	dynes/cm^2	0.2 dynes /cm^2			200	5 days			
Sea level currents	cm/sec	2			50	1 week			
Surface currents	cm/sec	20 m/sec				1 month		Critical areas only	
Sea ice extent	percent	2%			15-50	3 days			
Salinity	ppt	0.01 ppt			200	1 month			

IV. SATELLITE REQUIREMENTS

OF THE

NATIONAL OCEAN SERVICE

IV. SATELLITE REQUIREMENTS OF THE NATIONAL OCEAN SERVICE

In the United States, the National Oceanic and Atmospheric Administration (NOAA) is responsible for both weather and oceanographic services supporting a wide variety of users in both the civilian and military sectors. The National Weather Service (NWS) traditionally has focused the majority of its efforts and resources on weather services for land-based users (the general public, aviation, agriculture, etc.) because the majority of the user requirements stem from land-based operations. In November 1983, the Administrator of NOAA reorganized the National Ocean Survey to become the National Ocean Service (NOS), and instructed it to provide integrated services to mariners through activation of an Office of Ocean Services and establishment of an Ocean Products Center (OPC) and two prototype Ocean Service Centers (OSCs), in Seattle, Washington, and Anchorage, Alaska.

Under contract to NOAA, the Jet Propulsion Laboratory (JPL) published an "Ocean Services User Needs Assessment" (JPL Publication 84-19, April 5, 1984), which details ocean services requirements for various user communities and NOAA's present capabilities to satisfy these requirements. This assessment clearly revealed that more and better observations are needed from ocean areas to support generation of the many products required by marine user groups. Because of the remote nature of the areas to be observed and the scarcity of surface observation platforms, it is obvious that satellite remote-sensing technology will have to be applied to this problem. In addition, satellites offer unusual opportunities in the areas of international ocean data exchange, national and international marine broadcasts, and data collection from automatic surface stations on ships, buoys, offshore platforms, islands, and remote headlands.

The purpose of this document is to summarize NOS requirements for satellite data, products, and services for support to users until the year 2000. The contents are based in large part on a review and analysis of JPL Publication 84-19 (particularly chapters 5 and 6).

A. BACKGROUND

1. Status of the Requirements

Most requirements stated here have been under development for some time. They are dictated by the oceanic observation and data handling requirements needed to meet the NOS mission. They represent projections of future ocean user requirements, next-generation geostationary and polar orbiter satellite

plans (including special-purpose oceanographic satellites), and the requirements to deliver raw oceanographic observations and ocean guidance products to NOS and NWS offices, other countries, and some end users. These requirements draw heavily on national needs coordinated with the U.S. Navy and its Navy Remote Ocean Sensing System (N-ROSS) program.

a. Atmosphere-Ocean Coupling. In assembling systems to describe the variability of the oceans and atmosphere, NOAA/NOS finds it important to treat the oceans and the atmosphere as mutually dependent, coupled, fluid media, even though the precise nature of that coupling remains to be determined fully. The requirement to couple atmosphere and ocean models, in general, can be related both to the types and attributes of the models, modeling objectives (such as forecast length or geographical domain), and system constraints. Historically, atmospheric model outputs have been used to drive oceanographic models. Only in recent times has much thought been applied to the introduction of time-varying oceanographic model outputs to be fed back into atmospheric models.

Correct specification of the time-varying winds in the atmospheric boundary layer over a water surface plays an important role in many oceanographic models, such as spectral sea state, ocean currents, ice drift, water levels, and ocean thermal structure. The boundary layer winds explain a large fraction of the observed variability in these parameters. When an ice model has to account for growth and decay in addition to drift, air-ocean heat exchange has to be specified. The latter also is needed as an input to ocean thermal structure models.

b. Coupling Models of Varying Attributes. Even though NOAA/NOS places emphasis on describing the variability of marine weather and oceanographic conditions in the coastal zone, successful realization of this objective will not be achieved without taking a global perspective. Long period swell that affects offshore platforms, for example, may appear to be a local phenomenon, but the source of the swell may be thousands of miles distant.

The design and operational implementation of fine-mesh models for the coastal zone, therefore, presume the availability of time-dependent lateral boundary conditions from a model of comparable, if not identical, type whose domain is much larger, i.e., hemispheric or global in extent. In short, the oceans do not lend themselves to arbitrary partitioning in terms of local, regional, or global aspects.

c. Optimal Data Utilization. Although additional conventional observations can be taken in ocean areas, especially regions with few or no such observations, the validity of most

oceanographic products will depend, in large measure, on 1) the design and use of more advanced satellites and sensor systems and 2) the development of innovative methods to fully utilize satellite-sensed measurements of ocean state parameters. As in the acquisition of temperature profiles of the atmosphere over the oceans, there is no economically feasible alternative. If broad advances are not made using remotely sensed information, they probably will not be made at all.

Global and regional sea surface temperature analyses already benefit from large numbers of multi-channel sea surface temperature (MCSST) observations. On a typical day, about 50,000 MCSST observations are generated over the world's oceans. This is to be compared to the 5,000 ship reports received daily. The prediction of sea state, ocean currents, and ocean thermal structure has been improved by better predictions of ocean-area atmospheric pressure systems and associated marine-level winds, as a consequence of having large numbers of satellite temperature retrievals and cloud-track wind vectors available for the analyses of the atmosphere over oceanic areas.

Future satellite sensors may be capable of measuring additional ocean properties. Remotely sensed altimeter data will present new modeling opportunities of the oceans. Some of the sensors, such as the synthetic aperture radar, will severely tax available communications and data processing capabilities.

2. <u>NOS Mission</u>

Satellite data requirements within NOS result from specific responsibilities set by NOAA. As part of the NOAA reorganization of November 1983 (DOC Organization Order 25-5B), NOS was directed to: 1) establish requirements for ocean observations, and 2) coordinate ocean service programs throughout NOAA. Foremost among NOAA/NOS/NWS goals requiring satellite data are:

- Provision of accurate and timely marine and coastal weather forecasts to reduce loss of life and advance the national economy

- Provision of accurate and timely oceanographic forecasts of sea state, ocean currents, ocean thermal structure, tides and water levels, sea ice, vessel superstructure icing, etc.

- Provision of oceanic data in support of ocean research, climate studies, pollution monitoring, and value-added services to marine users

3. Areas of Special Importance to NOS

NOAA needs for wider access to imagery, and increased numbers and quality of atmospheric soundings, have been stressed in the previous chapter by the National Weather Service. NOS concurs with these needs and believes they are particularly important over ocean areas. In addition, NOS has unique requirements for observation of parameters not so commonly used in the provision of "meteorological" services. Some of these parameters are surface wind stress, sea state, subsurface thermal structure, water topography, currents, water color, and turbidity. The specialized measurement requirements that can be met by satellite sensor systems will be summarized in later sections of this chapter.

As part of a new Integrated Ocean Observation Program involving a diverse variety of sensor systems and platforms, NOS is planning a mix of new surface observation systems to be interrogated by satellites using Data Collection Platform (DCP) technology. Consequently, NOS has a rapidly expanding requirement for Data Collection System (DCS) communications support capabilities on U.S. satellites to retrieve and forward observations from systems such as:

- Manual-entry Shipboard Environmental (Data) Acquisition Systems (SEAS)
- Semiautomatic SEAS installations, including Expendable Bathythermograph (XBT) launchers, recorders, and digitizers
- Operational drifting buoys
- Coastal-Marine Automated Network (C-MAN) stations
- Small anchored coastal buoys
- Automated Water Level Measurement Systems (WLMS) for tide data

To handle these new observations, NOS requires that all U.S. geostationary and polar orbiter satellites have DCS communications capabilities and are configured to operate in both "self-timed" and "special interrogation" modes. It also is essential that Argos-type positioning be available to permit further automation of report generation for moving platforms such as ships and drifting buoys.

During the period covered by this document, a worldwide increase in the sharing of valuable oceanographic observations is a certainty. NOS is particularly interested in the rapid receipt of observations from foreign ships, buoys, and planned

European/Japanese oceanographic satellites. Full use of the 33 international channels on U.S. Geostationary Operational Environmental Satellites (GOES) for exchange of oceanographic data will be required.

As more products become available from the newly implemented Ocean Products Center, NOS foresees a growing requirement to broadcast these products directly to ocean users using GOES weather facsimile (WEFAX) technology. Before the year 2000, it is anticipated that as many as 40 ocean products per day will be added to GOES-WEFAX transmissions. Primary users for these broadcast products will be:

- Offshore oil and gas industry
- Ocean transportation industry
- Ocean mining industries
- Commercial fishing industry
- Construction and support industries
- Private forecasting and value-added service industries
- Climate community
- Sea grant and academic institutions
- NOAA activities
- U.S. Navy activities
- Foreign countries

NOS also has special in-house requirements for sea surface altimetry, ice topography, and gravimetry measurements in support of Charting and Geodetic Services (C&GS), and for water color/composition measurements in support of Marine Assessment and Coastal Resource Management programs. These can be partially met by existing satellite technology and are included in subsequent requirements tables.

B. OCEAN USER REQUIREMENTS

The major user groups identified previously have different requirements for satellite data and ancillary services such as surface platform interrogation, satellite broadcasts, and satellite data relay. In some cases, the users require raw satellite observations (or observations relayed by satellites from other collection systems). In other cases, the end user

requires an analysis of forecasts based upon satellite and other observations.

Table IV-1 presents an overview of ocean user requirements for satellite data (observations or products) and ancillary services. The table is stratified by general satellite type and shows in a quantitative manner the scope of each requirement (major, moderate, minor, or no/little importance to the user segment). For the polar orbiter satellites (weather or oceanographic), the requirement is foremost for data or services from U.S. spacecraft; however, the basic needs also apply to information from foreign environmental satellites. NOS is especially interested in receiving oceanographic observations from planned European and Japanese systems and, therefore, requires international data relay capabilities on all GOES systems.

It is essential that future U.S. polar orbiter and geostationary satellites have DCS communications capabilities. NOS is planning major expansions in its SEAS/XBT combination and its automatic WLMS. In order to eliminate manual input of a ship's position into SEAS/XBT reports, and to speed up the processing of drifting buoy reports and oil slick tracking, it is important that all future U.S. DCS systems include provisions for position location.

The stated NOS requirements for images and soundings from all U.S. systems are essentially the same as those specified by NWS. They are included in Table IV-1 to emphasize the importance of those observations to marine user applications; detailed specifications are not repeated in the NOS Composite Data Requirements tables at the end of this chapter because they are given in earlier NWS tables.

C. NOS OPERATIONAL REQUIREMENTS

1. Geostationary Satellite Data Products and Services

a. Images and Soundings. The requirements specified by NWS for images and vertical soundings of temperature and moisture from the Visible and Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS) and any follow-on sensors on GOES and GOES-Next satellites parallel NOS requirements for such observations. NOS requires the soundings, cloud motion winds, and sea surface temperatures from VAS to the extent they improve initial analyses (and subsequent numerical forecasts) of meteorological parameters over ocean areas. NOS also has a requirement for full-disk imagery from the Central Data Distribution Facility (CDDF) to be dispersed to major Ocean Service Centers (OSCs) for regional analysis and interpretation directly supporting marine users.

Table IV-1
Satellite Data and Services

SATELLITE TYPE / DATA OR SERVICE	OFFSHORE OIL/GAS	OCEAN TRANSPORTATION	OCEAN MINING	COMMERCIAL FISHING	CONSTRUCTION & SUPPORT	PRIVATE FCST & VALUE ADDED	CLIMATE COMMUNITY	SEA GRANT & ACADEMIC	NOAA INHOUSE
GEOSTATIONARY									
o Images	◑	●	◑	●	◑	●	◑	◑	●
o Soundings	⦶	⦶	⦶	⦶	⦶	●	◑	⦶	●
o OCS Data Services									
- SEAS/XBT	◑	●	⦶	●	⦶	●	◑	◑	●
- WLMS	◑	◑	⦶	◑	●	◑	⦶	◑	●
- Buoys	●	●	◑	●	◑	●	◑	●	●
- Platforms/Headlands	●	◑	⦶	●	◑	●	◑	●	●
o WEFAX Broadcast Services									
- Images	◑	●	◑	◑	⦶	●	●	◑	◑
- Marine Weather Charts	●	●	●	●	◑	●	◑	◑	◑
- Oceanographic Charts	●	●	●	●	◑	●	◑	◑	◑
o Ocean Data Relay Services	◑	◑	⦶	⦶	⦶	◑	●	⦶	●
POLAR ORBITER (MARINE WEATHER)									
o Images	◑	●	◑	●	◑	●	●	◑	●
o Soundings	⦶	⦶	⦶	⦶	⦶	●	●	◑	●
o Sea Surface Temp.	◑	◑	⦶	●	◑	●	●	◑	●

● MAJOR ◑ MODERATE ⦶ MINOR

Table IV-1 (continued)
Satellite Data and Services

SATELLITE TYPE / DATA OR SERVICE	OFFSHORE OIL/GAS	OCEAN TRANSPORTATION	OCEAN MINING	COMMERCIAL FISHING	CONSTRUCTION & SUPPORT	PRIVATE FCST & VALUE ADDED	CLIMATE COMMUNITY	SEA GRANT & ACADEMIC	NOAA INHOUSE
o Ice	●	●	⦶	●	●	◑	◑	◑	●
o Wind Stress	◑	◑	◑	◑	◑	◑	●	●	◑
o DCS Data Services									
- SEAS/XBT	◑	●	⦶	●	⦶	●	◑	◑	●
- WLMS	◑	◑	⦶	◑	●	◑	⦶	◑	●
- Buoys	●	●	◑	●	◑	●	◑	●	●
- Platforms/Headlands	●	◑	⦶	●	◑	●	◑	●	●
o DCS Locator Services									
- SEAS/XBT Ships	◑	●	◑	●	⦶	●	◑	◑	●
- Drifting Buoys	◑	●	⦶	●	⦶	●	◑	◑	●
<u>POLAR ORBITER (OCEANOG)</u>									
o Images	◑	●	◑	●	◑	●	◑	◑	●
o Soundings	◑	⦶	⦶	⦶	⦶	●	●	◑	●
o Sea Surface Temp.	◑	◑	⦶	●	◑	●	●	◑	●
o Ice	●	●	⦶	●	●	●	◑	◑	●
o Waves	●	●	●	●	●	●	⦶	◑	●
o Surface Winds	●	●	●	●	●	●	◑	◑	●
o Ocean Topography	⦶	◑	⦶	⦶	◑	◑	⦶	⦶	⦶

● MAJOR ◑ MODERATE ⦶ MINOR

Table IV-1 (concluded)
Satellite Data and Services

SATELLITE TYPE / DATA OR SERVICE	OFFSHORE OIL/GAS	OCEAN TRANSPORTATION	OCEAN MINING	COMMERCIAL FISHING	CONSTRUCTION & SUPPORT	PRIVATE FCST & VALUE ADDED	CLIMATE COMMUNITY	SEA GRANT & ACADEMIC	NOAA INHOUSE
o Gravimetric	Moderate	None	Moderate	None	None	None	None	None	Major
o Air/Ocean Heat Exchange	None	None	None	None	None	Minor	Major	Moderate	Major
o Color/Chlorophyll	Minor	Minor	None	Major	None	Major	Minor	Moderate	Minor
o Turbidity	Minor	None	None	Moderate	Minor	Minor	Moderate	Moderate	Moderate
o DCS Data Services									
- SEAS/XBT	Moderate	Major	Minor	Major	Minor	Major	Moderate	Moderate	Major
- WLMS	Moderate	Moderate	Minor	Moderate	Major	Moderate	Minor	Moderate	Major
- Buoys	Major	Major	Moderate	Major	Moderate	Major	Moderate	Major	Major
- Platforms/Headlands	Major	Moderate	Minor	Major	Moderate	Major	Moderate	Major	Major
o DCS Locator Services									
- SEAS/XBT Ships	Moderate	Major	Moderate	Major	Minor	Major	Moderate	Moderate	Major
- Drifting Buoys	Moderate	Major	Minor	Major	Minor	Major	Moderate	Moderate	Major
- Oil Slick Transponders	Major	Minor	None	None	Minor	Moderate	None	Moderate	Major

MAJOR ● MODERATE ◑ MINOR ⦶ NONE ○

NWS requirements for derived digital, imagery, and analog data from the VAS all fully satisfy NOS needs for processed data from this type of sensor system. NOS is particularly interested in semiobjective hurricane classification methods and marine cloud and weather analysis messages.

b. Data Collection System (DCS) Services. Subject to budget constraints, NOS is planning a major expansion in its Ocean Data Collection Program in the next 5 years. Preliminary plans call for new surface-based ocean observation initiatives, as follows:

- 100 manual-entry SEAS per year
- 80 semiautomatic SEAS systems equipped with XBT launchers and recorders per year
- 40 drifting buoys in operation at all times
- 10 new C-MAN stations per year
- 4 new coastal buoys per year
- 375 automated WLMS, for tide and other site-significant marine measurements, in operation by 1990

In addition, NOS is investigating Shipboard Acoustic Doppler Profilers, Automated Shipboard Aerological Programme (ASAP) radiosonde launchers, Expendable Current Profilers (XCPs), and Expendable Conductivity/Temperature/Depth (XCTD) Profilers. All of these new measurement systems are being designed to exploit DCP communications technology. These programs project a DCS communications requirement for GOES and/or polar orbiter satellites to handle at least 1,420 new ocean-oriented DCP installations by 1990; this figure does not include any increases planned by the NOAA Data Buoy Center (NDBC) for large, moored-buoy installations.

c. GOES-WEFAX Services. Under the auspices of the WMO, the United States is responsible for marine broadcasts for its assigned area. NOAA/NWS currently disseminates processed satellite images, meteorological charts, and alphanumeric products via an S-band, GOES-WEFAX service. WEFAX broadcasts are now acquired at approximately 160 locations (57 by foreign governments, 23 by the U.S. Government, and 80 by academic, commercial, and amateur stations). As the NOAA Ocean Products Center reaches full operation, it is expected to contribute up to 40 new ocean products per day to the daily WEFAX broadcast schedule. These products include:

- Sea state analysis and forecast guidance charts

- Current charts

- Ocean thermal structure (surface and subsurface) analysis charts

- Ocean color charts

- Water level anomaly charts

It is conceivable that the U.S may be required to activate a new GOES broadcast channel (OCEANFAX) in the future to handle these products. It is probable that new GOES broadcast receiver stations will be activated within the marine user community. Candidates include:

- Commercial fisheries associations

- Major harbormaster offices

- Shipping company offices

- Private ocean forecast service companies

- Sea grant institutions

2. <u>Polar-Orbiting Weather Satellite Products and Services</u>

The NOAA polar-orbiting satellites are designed primarily to provide data in support of numerical weather prediction models. However, the imagery also has high value in determining the extent of polar and Great Lakes ice cover, as well as water surface temperatures.

a. <u>Images.</u> NOS concurs with the NWS requirements stated for day and night cloud detection from U.S. polar orbiter weather satellites: cloud mapping/typing, jetstream identification, storm detection, differential cloud motion, etc. The Advanced Very High Resolution Radiometer (AVHRR) on NOAA's TIROS series satisfies NOS requirements for imagery. NOS is particularly interested in high-resolution (1 km) broadcast in real time via the High Resolution Picture Transmission (HRPT) system. One of the most critical problems in support of small boat (under 35 feet) commercial fishermen is accurate prediction and warning of small-scale severe weather phenomena approaching the coast (6-12 hour advisories are usually sufficient).

b. <u>Soundings.</u> NWS requirements for all-weather soundings from the TIROS Operational Vertical Sounder (TOVS) and the next-generation Advanced Microwave Sounding Unit (AMSU) do not satisfy NOS needs for atmospheric sounding from ocean areas. Neither sounder is capable of observing the detailed vertical

variation of the mass structure in the marine boundary layer (MBL). Thus, diagnostic MBL models cannot compute the marine wind or the vertical flux of horizontal momentum--both of which are of critical importance to oceanographic prediction models, especially spectral sea state models. New sensors and/or processing algorithms will be required to satisfy this NOS requirement. NOS strongly endorses the stated requirement for at least two polar orbiter weather satellites to meet coverage and timeliness limits for global soundings.

c. Sea Surface Temperatures. Providing environmental information to the U.S. commercial fishing industry to help it remain competitive with foreign fishing fleets is an important NOS goal. Recent studies have shown clearly that certain fish species have strong preferences for specific ocean temperature ranges; for example, most albacore tuna are caught within a few degrees of 62 ^{o}F, and salmon are seldom caught at temperatures much warmer than 52 ^{o}F. Sea surface temperature (SST) analyses and anomalies also are critical to the climate community. The NOS open-ocean requirements for scale-representative SST are $\pm$1.0 ^{o}C with a horizontal resolution of 10 km for daily analysis; the requirements for coastal zones and inland waters are more exacting. It appears that the AVHRR instrument can meet accuracy requirements but may have difficulty in satisfying resolution requirements for local SST analysis.

d. Ice Measurements. Studies of commercial user requirements reveal that accurate descriptions and specifications of sea ice characteristics are particularly important to offshore oil and gas industries operating in the Arctic area, and to ocean transportation and offshore construction and support industries serving Arctic oil and gas operations. U.S. commercial fishing fleets in the Alaska area frequently fish along the edges of the Bering Sea ice fields and also need accurate descriptions of ice extent and movement.

The Navy/NOAA Joint Ice Center (JIC) in Suitland, Maryland, is the nation's primary user of polar orbiter AVHRR data for analyzing ice conditions in the Arctic and Antarctic polar areas and the Great Lakes. Accurate ice descriptions also are critical to shipping operations on the Great Lakes and the St. Lawrence Seaway.

NWS requirements for sea ice extent shown in the NWS Composite Data Requirements tables do not fully address ice characteristics requirements needed by NOS; however, detailed requirements are presented in NOS Composite Data Requirements tables. It is doubtful if the polar orbiter weather satellites, as now planned, can satisfy these needs. (See later sections of this chapter for discussions concerning sensor

systems on planned polar orbiter oceanographic satellites.)

In particular, the JIC needs access to active all-weather satellite sensing capabilities and coarse-resolution, passive microwave sensors. While present ground processing systems are limiting, it is likely that high-resolution synthetic aperture radar (SAR) information will become extremely useful when NOAA's ground processing facilities are substantially upgraded.

e. Data Collection System (DCS) Services. NOAA polar orbiter weather satellites carry a data collection and platform location system. As specified previously, NOS is planning at least 1,420 new ocean-oriented DCP installations by the year 1990, and DCS capabilities are essential to the success of the NOS integrated Ocean Data Collection Program.

3. Polar Orbiter Oceanographic Satellite Products and Services

Although the Seasat satellite clearly demonstrated the utility of dedicated polar orbiter oceanographic satellites with sensors specifically designed for oceanographic measurements, the U.S. does not have such a system at the present time. The U.S. Navy's N-ROSS is planned for launch in 1990. However, NOS requirements for oceanographic satellite products and services stated in the following sections remain to be met.

a. Sea Surface Temperature. Sea surface temperature (SST) is a key oceanic parameter to be measured by oceanographic satellites. NOS requirements for accuracy, resolution, and frequency of coverage were given earlier in this chapter. The NOAA Ocean Products Center is developing new global SST analysis models that blend SST observations from all sources, including satellites, ships, buoys, XBT systems, CTD systems, and aircraft radiometers. For regional commercial fisheries applications, however, the emphasis is on fine-mesh local analyses capable of showing SST microstructure (e.g., local current shear and frontal zones where nutrients are most likely to concentrate).

Because of the lack of temperature profiles of the oceans, and the difficulty of inferring thermal structure at depth from surface temperature information, there is a compelling need for a new type of satellite-borne sensor (perhaps the blue-green laser) to obtain upper-ocean temperature information. It is not feasible to obtain such data coverage with surface platforms and expendable bathythermographs. Failing this type of development, the enormous disparity in the numbers of surface and subsurface temperature observations will increase rapidly with time.

For climate studies, the emphasis is on global or hemispheric SST analyses and sea surface temperature anomalies (SSTAs) from long-term normals. Since SSTA fields have normal annual ranges of about 0.5 °C to 2.0 °C (an average of about 1.0 °C) and SST measurement accuracies should be about one-fourth of the monthly variation to be studied, climate specialists would prefer a measurement accuracy of 0.25 °C. (Note: This is even higher than specified earlier in this report.)

Climate researchers believe a 3-day temporal resolution cycle is sufficient. Albacore fishermen working the early season tuna migration across the North Pacific Transition Zone prefer daily hemispheric analysis to pin down the location of the 60 °F to 64 °F band.

b. <u>Wind Stress and/or Surface Winds.</u> Surface wind stress is the major driving force in the generation of ocean waves and in the maintenance of ocean currents. Currents, in turn, play a major role in meridional transport of heat, while waves cause mechanical mixing that influences the depth of the upper mixed layer in the ocean. The mixed layer depth (MLD) is important to climate researchers because it is related to ocean heat storage and to fishermen because certain species prefer to feed within or below the thermocline, especially at night.

General Circulation Model (GCM) designers have developed typical accuracy requirements for wind stress of 0.2 dyn/cm^2 with spatial and temporal resolution requirements of 200 km and 5 days. U.S. Navy verification studies on their state-of-the-art Spectral Ocean Wave Model (SOWM) reveal that such models will not yield results any better than the wind fields that drive the model. Consequently, the Navy has found it very important to specify the surface wind field every 3 hours. NOS Composite Data Requirements tables, therefore, specify an absolute accuracy of $\pm$10 degrees in wind direction and $\pm$0.5 m/s in speed for boundary layer winds with spatial and temporal resolutions of 5 km and 3 hours, respectively, for regional problems.

The scatterometer on the Seasat satellite clearly demonstrated the utility of surface wind measurements from remote sensors. It is essential that the directional ambiguity problem is resolved before satellite winds are input to marine wind analysis models.

c. <u>Ocean Waves.</u> Assessments of user needs for ocean services revealed that analyses and forecasts of ocean waves (sea and swell) were the most important requirements overall. Sea state is the most important factor in Optimum Track Ship Routing (OTSR). It is critical to deep ocean mining industries

during mining string deployment/retrieval and ore transfer operations. It also determines whether small boat fishermen can operate with safety and frequently controls offshore construction and support operations.

While measurement of significant wave height (H-1/3) is the primary requirement, some oceanic applications such as ship routing and hull structure design ideally require specification of the wave energy spectrum as a function of both frequency and direction. NOS composite data requirements specify a maximum significant wave height accuracy of ± 0.5 m, with horizontal and temporal resolution of 5 km and 3 hours for regional applications.

The altimeter and the SAR flown on Seasat demonstrated the utility of wave observations from spacecraft. It is essential that U.S. polar orbiter oceanographic satellites be equipped with wave measurement systems. At least two such satellites are recommended to approach the required coverage.

d. <u>Sea Surface Topography.</u> Measurements of the dynamic height of the ocean surface are useful because the shapes are proportional to speeds in the large-scale current systems of the world. These currents are major factors in meridional heat transport and exchange; fluctuations in their intensity are keys to the monitoring of climate changes. Topography measurements also are useful in bathymetric mapping of seamounts. Climate researchers interested primarily in the fluctuations in major current systems specify accuracy requirements of ± 2 cm, with space and time resolutions of 50 km and 1 week, respectively.

e. <u>Tides.</u> Users of NOS tide data primarily are interested in combined astronomical/storm-driven water levels at coastal locations. Because of local variability due to bathymetry and land/sea topographic boundaries, NOS intends to focus on satellite DCS interrogation of automatic tide guage stations in its WLMS program. It also happens that water level measurement sites are strategic locations for measuring other significant marine-weather variables, such as coastal winds and air and water temperatures. It is essential that future U.S. oceanographic satellites have a DCP capability to retrieve these data. Specified NOS tide measurement accuracies are ± 5 cm.

f. <u>Ocean Currents.</u> While major current systems and their changes probably can be monitored through measurement of the sea surface topography, marine users also are interested in mesoscale eddies with horizontal dimensions of several hundred kilometers and life cycles of about 60 days. These eddies may be colder or warmer than the surrounding waters and exhibit dynamic height anomalies on the order of 50 cm. They are important to fishermen because certain parts of the eddies are

characterized by concentrations of nutrients (fish food).

NOS believes that smaller scale ocean currents also can be monitored by satellite. For the smallest features, specified accuracies are ± 1 cm/s for speed and 10 degrees for direction, with horizontal resolutions of 1 to 10 km and temporal resolution of 6 to 24 hours, depending on the size of the feature.

NOS also is investigating the use of Expendable Current Profilers (XCP) to measure surface and subsurface current structure. These systems require weather and oceanographic satellites to have data collection and position location systems.

g. Sea Ice. Sea ice is an important consideration in climate and General Circulation Model (GCM) studies. NWS has specified a requirement for sea ice extent measurements for these purposes, with horizontal resolutions of 15 to 50 km and revisit cycles of 3 days.

For operational support of ocean user activities such as Arctic oil and gas exploration, operations, and shipping, it is not sufficient to know only the extent. These sophisticated users require the following ice information:

- Ice edge limits
- Sea ice age (density)
- Sea ice thickness
- Sea ice percent coverage
- Ridge density/height/orientation
- Percentage/location of floebergs, growlers, and icebergs

While most polar orbiter weather satellites have an ice measurement capability, the altimeter and Synthetic Aperture Radar on Seasat clearly demonstrated the superiority of these sensors in making special ice measurements. Overall ice measurement requirements are listed in Composite Data Requirements tables at the end of this chapter.

It is important to NOS and the Joint Ice Center that ice data from Canadian and European satellites are received in the U.S. on a routine schedule.

h. Water Color/Chlorophyll Concentration. During a recent NASA/NOAA Fisheries Demonstration Project off the west coast of the United States, it was found that processed information from the Nimbus-7 Coastal Zone Color Scanner (CZCS) was very

useful in pinpointing optimum fishing areas. A number of different species tend to congregate at locations exhibiting the maximum horizontal contrast between deep blue oceanic water and upwelled, light green coastal water. Fishermen who first sought the optimum thermal band for a particular species and then found the best color contrast within the thermal band, and who fished inside the thermocline, brought in the largest catches (particularly for albacore tuna).

To support U.S. commercial fisheries needs, water color/chlorophyll concentration charts must be prepared for all coastal areas--preferably out to at least 500 nm--several times a week so as to reflect constantly changing conditions. While the CZCS provides valuable data, the coverage is limited to cloudless days, and the amount of computer processing required is prohibitive except for high-priority areas. These problems need to be solved before future operational ocean color imagers are deployed.

NOS composite data requirements for water color/chlorophyll concentration specify an absolute accuracy of ±30 percent (in mg/L), with spatial and temporal resolutions of 1 km and 24 hours, respectively, for regional/local mapping.

i. Turbidity. Turbidity measurements are used for monitoring pollution and river discharges in coastal waters, and also have been useful to commercial fishermen seeking mud bottom dwelling species. Both visual radiometers and the CZCS sensors have proven capabilities for turbidity measurements.

NOS composite data requirements specify absolute accuracies of ±30 to 40 percent (in g/m^3), with horizontal resolution of 1 km and a revisit cycle of 12 hours. Coastal areas out to 500 km are most important.

j. Surface Salinity. Salinity determines the freezing point of seawater and its vertical density structure (stability). Because salinity is largely controlled by the difference between evaporation and precipitation, or river discharges, it is considered an important indicator of climatic conditions. NWS has specified an observational accuracy of 0.01 ppt (judged by NOS to be very high), with a horizontal resolution of 200 km and a temporal resolution of 1 month. Should satellite-borne salinity sensors become a reality, NOS could accept an observational accuracy of 0.5 ppt, 200 km, and 1 month for global analyses. For monitoring coastal changes in surface salinity, such as outside bays and river mouths, NOS requires spatial and temporal resolution on the order of 0.2 ppt, 10 km, and 3 days.

k. Surface Heat Exchange. Researchers have a need to know the air-sea temperature difference or surface heat exchange

patterns--preferably on a global scale--for climate studies and numerical forecast model work. NOS has specified heat exchange measurement accuracies of ± 50 W/m^2 with spatial and temporal resolutions of 50 km and 12 hours.

4. Oceanographic Satellite Capabilities of Interest to NOS

The NOS oceanographic satellite measurement requirements were discussed earlier in this chapter. There are a number of current and planned U.S. satellites capable of satisfying major portions of these overall requirements. Table IV-2 indicates the extent to which the most important ocean parameters of interest to NOS can be measured. Table IV-3, from the same source, provides a more detailed summary of the capabilities planned for the N-ROSS satellite. This system will go a long way toward meeting NOS requirements for oceanographic data from spacecraft in the foreseeable future.

Table IV-4 presents a summary of foreign satellites and planned sensor systems of interest to NOS because of their oceanographic measurement capabilities. Considering the uncertainties in procurement of U.S. oceanographic satellite systems, it is essential that the U.S. makes firm plans for exchange and receipt of data from foreign systems.

D. COMPOSITE DATA REQUIREMENTS SUMMARY

Requirements for cloud imagery and atmospheric measurements from geostationary and polar-orbiting satellites specified by NWS are generally satisfactory for NOS application and, therefore, are not readdressed in this chapter. Requirements for observations and ancillary services that are primarily oceanographic in nature are specified in Tables IV-5, IV-6, and IV-7.

Table IV-2
U.S. Oceanographic Measurement System Capabilities of Interest to NOS

		System Capabilities							
		Current				Planned			
Parameter	Measurement Unit(s)	DMSP	NOAA	GOES	LANDSAT	GEOSAT	DMSP (a) (SSM/1)	NROSS	TOPEX
Precipitable Water	cm/cm^2						●	●	
Precipitation Rate	cm/hr			○			●	●	
Surface Winds	s = m/s d = degrees			◑		◑	◑	●	◑
Surface Air Temperature	°C								
Sea Surface Temperature	°C	●	● (b)	◑ (d)	○ (f)		●	● (j)	
Wave Directional Energy Spectra	h = m ℓ = m d = degrees					◑		◑ (h)	○
Sea Ice Conditions	C = 1/8(oktas) A = 1,2,M yrs. T = cm L = km				◑ (e)		◑	●	
Surface Currents	s = cm/sec. d = degrees	◑	◑		○	●	◑	●	◑
Tides (Astronomical & Storm)	cm					●		●	◑
Salinity at the Surface	ppt							○ (g)	
Chlorophyll Concentration	μg/ℓ		(c)		◑				
Water Turbidity	mg/ℓ or g/m^3				◑				
Shallow Water Bathymetry	m				○			◑ (i)	◑ (i)
Oil Spills (Sheen Stage)	E = km T = mm	◑	◑		◑		◑	◑	◑

● Primary
◑ Secondary/Partial Capability
○ Developmental Sensor/Capability
☐ No Capability

(a) DMSP with microwave scanner.
(b) Superior to DMSP in accuracy.
(c) CZCS addition proposed.
(d) Lacks mid and high latitude coverage.
(e) Data timeliness precludes use.
(f) TM infrared.
(g) Low frequency radiometer 5 to 10 GHz.
(h) H 1/3 only.
(i) Deep water only.
(j) All weather SST.

Table IV-3
Capabilities of the Planned Navy N-ROSS Satellite

Parameter	Measurement Unit(s)	Accuracy (±)	Precision (±)	Measurement Range	Spatial Resolution (km)	Temporal Resolution (Frequency)	Acceptable Time Delay	Area Coverage	Data Grid Size Format
Precipitable Water	cm/cm^2	◑	◑	●	◑	●	●	●	●
Precipitation Rate	cm/hr	◑	◑	●	◑	●	●	●	●
Surface Winds	s = m/s d = degrees	●	●	●	◑	◑	●	●	●
Surface Air Temperature	°C								
Sea Surface Temperature	°C	●	●	●	●	◑	●	◑	●
Wave Directional Energy Spectra	h = m	●	●	●	◑	◑	●	◑	●
	m = degrees								
Sea Ice Conditions	c = 1/8(oktas) A = 1,2,M yrs. T = cm L = km	◑	◑	●	◑	●	●	●	●
Surface Currents	s = cm/sec. d = degrees	◑	◑	◑	◑	○	●	○	◑
Tides (Astronomical & Storm)	cm	◑	◑	●	◑	○	●	○	◑
Salinity at the Surface	ppt	○	○	○	◑	◑	●	◑	◑
Chlorophyll Concentration	μg/ℓ								
Water Turbidity	mg/ℓ or g/m^3								
Shallow Water Bathymetry	m	◑	◑	○	◑	●	●	○	○
Oil Spills (Sheen Stage)	E = km T = mm	○	○	○	◑	◑	●	◑	◑

● Complete (meets requirements) ◑ Partial ○ Minimal capability ▭ No capability (a) Seamounts in deep water.

Table IV-4
Foreign Satellite Systems of Interest to NOS Oceanographic Measurement Requirements

				MICROWAVE RADIOMETERS		RADARS			V&IR RADIOMETERS	
SATELLITE	SPONSOR	APPLICATION	STATUS	ATMOS	SUR	ALT	SCAT	SAR	ATMOS	SUR
SPOT-1	FRANCE	HIGH RESOLUTION STEREO IMAGING	85 LAUNCH							HRV
SPOT-2	FRANCE	TOPOGRAPHIC, GEOIDAL MAPPING	89 LAUNCH, POSS. TOPEX COOPER-ATIVE MISSION			ALT				
RADARSAT	CANADA	OPERATIONAL ARCTIC OBSERVATIONS	PRE-IMPLEMENTA-TION DESIGN & TEST 89/90 LAUNCH					SAR		V&IR
SHUTTLE	DFVLR	EXPERIMENTAL MICROWAVE MEASUREMENTS			MRSE		MRSE	MRSE		
ERS-1	ESA	OPERATIONAL OCEAN OBSERVATIONS	IN DESIGN & MANUFACTURE 88/89 LAUNCH			ALT	AMI	AMI		
METROSAT AND GMS	ESA JAPAN	GEOSYNCHRONOUS WEATHER	ON GOING PROGRAM						X	X
MOS-1	JAPAN	MARINE OBSERVATIONS	85 LAUNCH	MSR						VNIR VTIR
MOS-2	JAPAN	MARINE OBSERVATIONS	90 LAUNCH	MSR	SSR	ALT	SCAT			VNIR VTIR
JERS-1	JAPAN	GLOBAL IMAGING	90 LAUNCH					SAR		

Table IV-5
NOS Composite Data Requirements (1985-2000) - Basic Observations

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Cloud images**	—	—	—	—	8	Hourly, composite primary data	—	Hemisphere	—	M
Vertical atmosphere profiles**	K	2 2.5	— —	surface-150 mb surface-0.4 mb	50 50-250	3 6-12	—	Conus Regional/global	— —	I
Precipatation measurements**	inches	20%	—	—	7	Hourly	5 min	Conus	—	M
Upper troposphere winds**	m/sec	7 m/sec	—	150-400 mb	350	6	1.5	Global	—	I+
Cloud statistics and derivations**	—	—	—	—	4	0.5	5-10 min	Global	—	I
Boundary layer winds (direction and speed)	degrees m/sec	±10-20 ±0.5-2	—	0-360 0-100	5-20	3-12	1-6	Regional Global	10-100 —	I+ I+++
Surface wind stress	dynes/cm^2	0.1	—	0-10	10-50	6-12	3-6	Regional Global	10-100 —	M
Range rate between two satellites	microns per sec	0.1-1	0.1-1	0-15,000	—	1.4 sec	—	Global	—	M

* I - Immediate need
M - Midterm, early 1990's

** See NWS composite primary data requirements

Table IV-5 (concluded)
NOS Composite Data Requirements (1985-2000) - Basic Observations

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority
Surface heat exchange	W/m^2	±10-50	--	0-2000	10-50	6-12	3-6	Regional Global	10-100	M
Surface topography	cm	±2	--	0-50	10-20	6-12	3-6	Regional Global	10-100	I
Wave height	m	±0.5-1	--	0-50	5-20	3-12	1-6	Regional Hemis. Global	10-100	I++ to I+++
Tides	cm	±5-10	--	0-1500	1-50	3-12	1-6	Regional Global	10-100	M
Surface currents	cm/sec	±5-10%	--	0-500	5,10,50	6-96	3-48	Regional Hemis. Global	10-100	M to I+++
Sea surface temperature	°C	±0.5-1	--	-5 to 35	1,5,10	12-24	6-12	Regional Hemis. Global	1-50	I++ to I+++
Chlorophyll concentration	mg/l	30%	--	0.01-100	1	24	12	Local Regional	5-10	M+
Turbidity	g/m^3	30-40%	--	0.01-100	1	12	12	Regional Hemis.	5-10	M

Table IV-6
NOS Composite Data Requirements (1985-2000) - Sea and Lake Ice

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Edge	km	1	1	NA	Line position	24	24	Regional	—	I
		10	10	NA	Line position	72	72	Global	—	I
Cover	tenths	0.5	0.5	0-10	0.01	3	3	Local	0.01	I
		1	1	0-10	1	24	24	Regional	1	I
		1	1	0-10	50	72	72	Global	50	I
Thickness**	cm	10	5	0-5000	0.01	3	3	Local	0.01	I
		10	5	0-500	1	24	24	Regional	1	I
		10	5	0-500	50	72	72	Global	50	I
Type	age (cm)	New(0-10) Young (10-30)	Age category	New-old	0.01	3	3	Local	0.01	I
		1st yr thin (30-70)			1	24	24	Regional	1	I
		1st yr med (70-120) 1st yr thick (120-200) Old Ice (>200)			50	72	72	Global	50	I
Drift	km	1	1	0-50	0.5	24	3	Local/ regional	--	I
Topography	nondimension index	1	1	0-100	5	3	3	Global	—	I

* I - Immediate need

** If thickness cannot be directly measured, then it can be inferred from satellite sensor signatures.

Table IV-6 (concluded)
NOS Composite Data Requirements (1985-2000) - Sea and Lake Ice

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority
Ridge density	percent	10	10	0-100	0.001	3	3	Local	0.001	I
Ridge orientation	degrees	10	10	0-360	0.001	3	3		0.001	I
Ridge height	m	1	1	0-50	0.001	3	3		0.001	I
Floebergs	m	1	1	1-50	0.001	3	3	Local	0.001	I
Growlers/ icebergs	m	1	1	1-100,000	0.001	3	3	Local	0.001	I

Table IV-7
NOS Composite Requirements (1985-2000) - Auxiliary Satellite Services

Service	Requirement
Data collection system (all satellites)	• Data collection and position location services for at least 1,835 new ocean platforms by 1990 and 5,000 platforms by 2000
GOES WEFAX broadcast (OCEANFAX?)	• Broadcast capabilities for up to 40 new ocean products (charts and alphanumerics) • Receipt/processing/display capabilities for at least 11 new user stations by 1990 and a possible 50 new ocean-user stations by 2000
GOES international ocean data exchange includes telecommunications link with Canada	• 45% full-time, 100 bps data channels on GOES-West for receipt of Japanese data • 45% full-time, 100 bps data channels on GOES-East for receipt of European data

V. SATELLITE REQUIREMENTS
OF THE
OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

V. SATELLITE DATA REQUIREMENTS OF THE OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

Oceanic and atmospheric processes traditionally have been investigated by sampling from instruments in situ, which yield quantitative measurements that are intermittent in both time and space. Over the last several decades, satellite sensors have been developed that have yielded important new measurements in these four dimensions. The need to obtain proper sampling of input quantities in existing or proposed analytical and numerical models is probably the most significant limitation on the advancement of our physical understanding of atmospheric and oceanic processes. It is generally recognized that satellite sensors offer an important advancement in global measuring techniques when used in conjunction with ground-based measurements.

Measurements from present satellites have demonstrated their usefulness. For example, NASA research and development spacecraft (Seasat and Nimbus) and the NOAA operational spacecraft (GOES and POES) have shown that satellite measurements can play an important role for both operational analysis and research on the lower atmosphere, oceans, and near-Earth space environment. However, additional research is needed to ensure that future sensors are based on new technology and not on technology developed in the 1970's, when many of the current satellite sensors were designed. This research would ensure that the limitations of the existing satellite sensors would be addressed.

The need for frequent and accurate measurements of the ocean, atmosphere, and near-Earth space environment has increased dramatically during the last decade. The purpose of the present report is to specify the requirements for future satellite sensors. These requirements have been evolving within NOAA over the last 10 to 20 years.

The future satellite requirements of the Office of Oceanic and Atmospheric Research (OAR) cover a wide range of needs, from ocean and atmosphere research to operational space environmental services. Satellite sensing of the oceans and atmosphere offers a unique opportunity both for global observations needed as input to geophysical models and for the research needed to improve these models. Satellite sensing of the near-Earth space environment is needed for service activities, including monitoring reports, issuing alerts, and forecasting solar-terrestrial events.

For understanding the global weather and climate systems, no measurements are more important than winds and tropical

precipitation. Satellite sensors for providing wind profiles (e.g., Windsat) in conjunction with ground-based systems and for providing quantitative estimates of tropical precipitation, especially over the oceans, should be given highest priority in planning for the year 2000.

A similarly broad, generic approach to global biological and chemical processes should be taken, and priority should be placed on a satellite sensor such as the Ocean Color Instrument (OCI) that will provide information on oceanic biomass and its changes. This approach should yield invaluable data for productivity and fisheries investigations and, if new hypotheses are correct, should indicate changes in the biological controls mediating many global tropospheric chemical reactions and exchanges with the ocean.

A. FUTURE APPLIED RESEARCH REQUIREMENTS

1. Atmosphere

Remote sensing plays an integral role in meteorological field experiments. Over the past two decades, these experiments have evolved into complex programs involving numerous researchers and many resources as investigators face the need to study weather on increasingly finer time and space scales. Satellites are extremely important platforms for research, sensing various meteorological parameters on space and time scales not possible with conventional systems. For example, in many instances the synoptic scale rawinsonde network and the climatological gauge network are not sufficiently dense nor do they acquire measurements frequently enough to document the phenomena of interest. Remote sensors on geostationary satellites fill the data gap between ground-based networks and aircraft observing systems. The former are sparse networks and usually provide infrequent measurements; the latter provide finely resolved observations, but over narrow paths and only on special occasions. Satellites bridge the gap, make frequent and routine observations, and serve as a vital medium for communications and data transmissions for field experiments.

The process of numerical weather prediction classically is viewed as an "initial value problem," wherein the governing equations of geophysical fluid dynamics are integrated forward from determined values of the meteorological field at some initial time. Solving this "initial value problem" is very difficult, given the properties of geophysical fluids, the complexities of atmospheric processes, and the nonlinearity of the equations. Even if the mathematical equations were solvable, half of the problem would remain, that is, the difficulty of accurately determining from real observations of the

real atmosphere the initial values of many time-dependent quantities.

Ideally, observations should specify values for each parameter at the initial time, $t = 0$. This ideal case is never realized, for several reasons:

- Conventional pressure, temperature, and wind observations taken at synoptic times, 0000 GMT and 1200 GMT, are inadequately sampled globally, leaving geographic holes in the input data.

- Conventional observations are subject to significant random instrument errors.

- Remote satellite observations of vertical temperature profiles go a long way toward providing a homogeneous global coverage. These observations are not synoptic, however, but are distributed in space and time following the satellite orbit.

- Remote satellite observations of cloud motion from geostationary satellites, used to infer winds, are available at synoptic times, but the vertical resolution, limited to one or two levels, is grossly inadequate.

- Indirect satellite observations always involve physical assumptions and sophisticated data processing for reconstructing the meteorological parameters.

Future weather satellite programs must be carefully planned, so that these problems can be addressed properly.

2. <u>Oceans</u>

There is a variety of satellite observations that, if available continuously over several years and reduced to a form designed for research use, would supply a needed data set for numerical and analytical ocean models. These models are important for providing a detailed description of ocean parameters and, hence, a better understanding of ocean physical processes.

Models of various types are becoming increasingly powerful tools by which diverse observations of the ocean are tied together. A number of models, based on the equations of motion, address the general circulation in the world's oceans. The goal of these models is to determine the circulation, heat content, horizontal heat flux, and variability of the oceans, which are important for both marine weather and climate studies.

For example, a general circulation model normally assumes fields of surface wind stress, surface temperature, and net precipitation minus evaporation. The model predicts mean fields of subsurface temperature, salinity, and velocity, together with sea level and surface heat flux. Varying the inputs allows the model to be used to determine the sensitivity of the ocean to variations in parameters. If the mathematical models are solvable, half the problem still remains, as with the atmosphere; that is, obtaining accurate input parameters from observations of the real ocean. Therefore, future marine weather and climate programs also must be carefully planned, so that the proper satellite sensor inputs are obtainable for the different ocean models.

3. Space Environment

OAR/Environmental Research Laboratories (ERL) space environment services are provided to the public, corporations, and various entities of the Federal Government. Historically, NASA and DOD have been the agencies most heavily dependent on the products of the Space Environment Services Center (SESC). The SESC continuously monitors and predicts the solar activity that leads to Earth events in the upper atmosphere, the magnetosphere, and the ionosphere that affect communications, electric power systems, air and marine navigation, and Earth satellite functions.

The Solar-Terrestrial Program of ERL's Space Environment Lab (SEL) is unique in OAR, since it contains both research and services; the major user of the research is the services component. Because of the currently primitive state of space weather service, such close liaison is essential in developing more sophisticated predictive techniques. To better understand the physical processes causing the disruptive events reported by SESC, guidance must be given to the service component from research models. Such models are constructed from real-time data provided by SESC from space and ground-based monitors. These data are augmented with data sets acquired by satellite sensors that are off line from strictly service uses. Thus, SEL satellite data requirements for the next 15 years are not solely for utilization in environment services, but also are the R&D investment for developing the services techniques needed by the year 2000.

B. REQUIREMENTS OF FUTURE SATELLITE SENSORS

1. Atmospheric Sensors

The age of remote sensing in the field of meteorology began with the launch of the first Television and Infrared Observation Satellite (TIROS) on April 1, 1960. From this beginning, which provided only simple black and white photos of

clouds, satellite observations have come to include data from scanning radiometers operating in the visible, infrared, and microwave segments of the spectrum. Their resolutions have been improved both spatially and temporally, and their data are used to measure or infer a number of atmospheric parameters, such as winds at multiple levels, Earth albedo, surface precipitation, and the vertical distributions of temperature and moisture.

Remote sensing of the atmosphere has many roles to fulfill in the wide variety of space and time scales that represent the current state of atmospheric research. Observational requirements for problems that relate to climate can generally be fulfilled by polar-orbiting satellites (precipitation is one exception, because of its diurnal variation, even over open ocean), whereas phenomena that change more rapidly (e.g., convective systems of all scales) require observation from geostationary platforms.

a. <u>Mesoscale Convective Systems</u>. OAR scientists have made major discoveries in the field of mesoscale meteorology, and OAR will be one of the principal players in the Storm-scale Operational and Research Meteorology (STORM) program. Measurements of the dynamic, thermodynamic, and microphysical properties of mesoscale convective systems are needed for both phenomenological and numerical modeling studies of these systems. In addition to the visible, infrared, and moisture channel pictures that historically have been available from weather satellites, the parameters needed to investigate mesoscale systems and are amenable to remote observation are as follows:

- Surface temperature
- Vertical temperature profiles
- Vertical moisture profiles
- Vertical profiles of boundary layer winds
- Vertical profiles of winds above the boundary layer
- Precipitation occurrence
- Precipitation rate
- Lower tropospheric moisture gradients
- Cloud top heights and temperatures
- Precipitation type (rain versus hail)
- Total ozone
- Soil moisture

Present satellite sounding configurations are limited to clear air soundings. Requirements for sounding retrievals from cloudy regions exist as well. Table V-1 gives detailed observational requirements for these parameters.

b. <u>Numerical Weather Prediction</u>. The utilization of satellite data in numerical weather prediction has two aspects, model initialization and verification of model results. The

effects on model performance of using satellite measurements of atmospheric parameters to fill data-sparse or data-void areas is under investigation. The utility of satellite-inferred precipitation for verifying models is yet to be determined.

A fertile area of research is the concern with the meshing of ground-based and satellite-based observations. For example, is it possible to create a vertical temperature profile, useful in numerical models, from ground-based Profilers and the satellite soundings?

The parameters that satellites can provide for model initialization include:

- Vertical temperature profiles
- Vertical wind profiles
- Vertical moisture profiles
- Cloud top heights
- Precipitation

Table V-2 gives detailed observational requirements for these parameters.

2. Ocean Sensors

In 1978, the low-orbiting satellite, Seasat, was flown with four active and passive microwave sensors dedicated to oceanographic measurements. The active microwave instruments were: a radio scatterometer used for measuring winds; a radio altimeter used for measuring ocean wave heights and the ocean geoid (from which geostrophic currents can be calculated); and the Synthetic Aperture Radar (SAR) used for measuring ocean waves, fronts, mesoscale eddies, and ice boundaries. The fourth sensor was the Scanning Multichannel Microwave Radiometer (SMMR) used for measuring sea surface temperature and monitoring sea ice conditions. These sensors demonstrated the feasibility of real-time satellite measurement of surface winds, ocean currents, and wave heights based on scatterometer and altimeter data. Further research is needed before the microwave radiometers and synthetic aperture radars can be used continuously for operational needs. Within the next 5 to 10 years, a new series of satellites is planned, dedicated to oceanographic measurements. These satellites include:

- N-ROSS, approved for launch in 1990, with active and passive microwave sensors aboard. This U.S. Navy spacecraft will carry sensors similar to Seasat, except synthetic aperture radar will not be included.

- ERS-1, approved for launch in late 1989, with active and passive sensors aboard. This European Space Agency (ESA)

spacecraft will carry sensors similar to Seasat, including dual mode synthetic aperture radar.

- TOPEX, proposed for launch in 1990, with an advanced radio altimeter designed to measure sea surface elevation to within a few centimeters. In addition to the advanced altimeter, this NASA spacecraft will carry an experimental Global Positioning System (GPS).

The future requirements for ocean observations have been determined primarily by considering the results from the Seasat sensors. These Seasat sensors and other proposed sensors can provide important new information for numerous ocean programs within OAR, including climate research, marine resources and services, marine operational and prediction services, and marine assessment research and services.

a. <u>Climate Research</u>. The tropical ocean is likely the most dominant element affecting interannual climate variations. Indeed, the Tropical Ocean Global Atmosphere (TOGA) program has shown that causal relationships do exist between large-scale changes in the tropical ocean thermal structure and major atmospheric flow patterns. The required inputs for the climate models being developed in the TOGA program can most easily be obtained from satellite sensors. These parameters are:

- Sea surface temperature
- Surface wind velocity
- Precipitation
- Surface topography (geostropic currents)
- Cloud cover
- Liquid water and ice content

Table V-3 gives more detailed data requirements for climate studies.

b. <u>Marine Resources Research and Services</u>. OAR develops and transfers scientific information to support decisions pertinent to marine pollution, exploitation of marine resources, water utilization, coastal power generation, and other activities affecting marine ecosystems. Research activities focus on coastal regions, estuaries, and the Great Lakes. Satellite sensors are useful for observing the ice, snow, and moisture in and near the Great Lakes and Alaska. The data required in these areas are as follows:

- Ice extent
- Ice thickness
- Ice albedo
- Ice surface temperature
- Ice concentration

- Snow cover extent
- Snow cover moisture equivalent
- Soil moisture
- Aquatic plant biomass

Table V-4 gives the detailed data requirements for the ice, snow, and moisture measurements.

c. Marine Observations and Prediction. This research improves the capability of providing services to the marine community through increased understanding and improved observations of the behavior of the atmospheric boundary layer over the oceans, the waves and currents in the surface layer, and the physical properties of the surface and subsurface waters of the oceans. Observations in which the global all-weather coverage by satellite sensors can be used effectively are as follows:

- Surface winds
- Surface waves
- Storm surge
- Hurricanes
- Sea surface temperature
- Ocean currents
- Ocean color/chlorophyll

Storm surges and hurricanes are natural phenomena that, because of the destructive environments surrounding them, can best be observed remotely by satellites. Table V-5 gives detailed data requirements for the observable ocean parameters.

d. Data Transmission and Verification. The transmittal of research and operational ocean data via satellite has been a service since about 1970. Many environmental research programs rely on the GOES geostationary spacecraft for data transmission from sensor platforms in remote locations and for verification that the platform sensors are working properly. Expansion of these services is essential to numerous research programs. Table V-6 gives the requirements for the existing data transmission system.

3. Space Environment Sensors

The primary causes of all space environment disturbances are found at the sun. Various forms of solar activity start chains of events that cause reactive processes at the Earth, ultimately leading to disturbances in systems important to humankind. It is the mandate of the ERL/SEL Space Environment Services Center to monitor the links in such chains and, in so doing, to predict the terrestrial effects.

Because of the primitive state of space environment services,

predictions of the terrestrial effects of observed solar events often cannot be made with certitude. While it is impossible today to specify the complete solar-terrestrial linkage in terms of systems of physical laws and equations that connect events in the interior of the sun to Earth events, some limited correlative segments of this process are predictable with proper input data.

NOAA is required to provide the necessary data sets of those solar physical parameters for which service use can be made. As with meteorological forecasting, a tradeoff must be made between lengthening the lead time of a prediction and increasing its reliability. For the typical mix of SESC customers with varying needs, long-range crude predictions must be provided along with more accurate short-term alerts.

With changes in the state of the art, opportunities occasionally present themselves for improvements on one front or the other--either in accuracy or in lead time--and must be exploited. NOAA must avail itself of opportunities for improving the products of the ERL/SEL space weather services between now and the year 2000.

Specific sensing needs, required over the next 15 years by the SEL, have been listed in Table V-7. In this list, the same natural phenomenon may appear more than once. Rather than duplications, these multiple appearances are aimed at gaining data sets that help provide either short-term reliable forecasts or longer lead-time predictions of the gross aspects of coming events.

a. <u>Geostationary Orbit Requirements</u>. Fully sunlit spacecraft in geostationary orbits must be used for remote sensing of the sun, to detect the incipient solar wind, and to measure the other space environment parameters requiring near-continuous monitoring. Geostationary vehicles also provide in situ monitoring of their local environments and carry ionospheric radio beacons.

- Solar remote sensing includes observing the parameters of flares, coronal mass ejections, and radio bursts at the surface of the sun.

- Incipient solar wind remote sensing includes detecting coronal mass ejections carried on the incipient solar wind.

- Geostationary environment (in situ) sensing includes measuring plasma, particle, and field parameters at the satellite's location.

- Radio beacon support provides the means for ionospheric total electron content determinations and observing their longitudinal variations.

b. Polar Orbit Requirements. Polar-orbiting spacecraft are required for remote sensing of the polar caps of the Earth, for in situ monitoring over the polar regions, and for carrying ionospheric radio beacons. Polar orbiters represent economical vehicles for the remote sensing of those solar parameters not requiring high cadence rates.

- Polar cap remote sensing includes auroral imaging.

- Polar orbit environment (in situ) sensing includes measuring plasma, particle, and field parameters along the satellite's orbital path.

- Radio beacon support provides the means for ionospheric total electron content determinations and observing their latitudinal variations.

- Solar remote sensing includes observing sunspots, magnetohydrodynamic flows, filament disappearances, EUV flux, X-ray coronal holes, and vector solar magnetic fields.

c. Libration Point Sensor. Ambient conditions in the solar wind must be monitored by a vehicle at the L^1 libration point before encountering the Earth's magnetosphere.

- Solar wind (in situ) sensing includes measuring plasma, particle, and field parameters at the satellite's location.

d. Platform Items for Common Usage. Generic features that would serve all NOAA organizations are as follows:

- Advanced data collection systems, used for retrieval of remote data caches

- Quick-reaction pad (reserve power and space on the satellite), used for instrument development and state-of-the-art breakthroughs (Table V-8)

Table V-1
OAR Composite Data Requirements (1985-2000) - Mesoscale Phenomena

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Surface temperature	°C	1-2 °C	--	-30 to 50 °C	5-25	0.1-1	0.5	Mesoscale	NA	I
Temperature	°C	1-2 °C	0.5-5 km vertical resolution	-110 to 50 °C	20-100	0.5-3	0.5	Mesoscale	NA	I
Moisture profile	% relative humidity	5-15%	0.5-5 km vertical resolution	0 to 100%	10-50	0.5-3	0.5	Mesoscale	NA	I
Boundary layer wind profile	speed: m/s dir: deg.	1-3 m/s 10°	0.2-1 km vertical resolution	0-100 m/s	10-50	0.2-1	0.5	Mesoscale	NA	I
Wind profile above boundary layer	speed: m/s dir: deg.	1-3 m/s 10°	1-5 km vertical resolution	0-100 m/s	20-100	0.5-3	0.5	Mesoscale	NA	I
Precipitation occurrence	yes/no	NA	--	NA	5-50	0.1-1	0.5	Mesoscale	NA	L
Precipitation rate	mm/h	20-50%	--	0-10 mm/h	5-50	0.1-0.5	0.5	Mesoscale	NA	I
Lower tropospheric moisture content	% relative humidity	10-25%	--	0-100%	3-15	0.1-0.5	0.5	Mesoscale	NA	M
Cloud top height	m	250-500 meters	0.25 km vertical resolution	0-20	0.5-10	0.01-0.25	0.25	Mesoscale	NA	M
Cloud top temperatures	°C	1		-90 to 30 °C	0.5-10	0.01-0.25	0.25	Mesoscale		M
Soil moisture	5 categories				10-20	Weekly		Mesoscale		M
Precipitation type	rain/hail		--	NA	1-10	0.01-0.1	0.25	Mesoscale	NA	M
Total ozone	Dobsons	10 Dobsons	--	150-650 Dobsons	25-50	1-3	0.5	Mesoscale	NA	M

* I - Immediate need; M - Midterm, early 1990's; L - Late 1990's

Table V-2
OAR Composite Data Requirements (1985-2000) - Numerical Weather Predictions

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Temperature profiles	°C	Tropos. 0.5-1 °C Stratos. 1-2 °C	0.5m-2km vertical resolution	-110 °C to 50 °C	100	6	1	Global	100	I
Wind profiles	speed: m/s, dir: deg.	Tropos. ±1-2 m/s, ±10 °C; Stratos. ±2-3 m/s ±10 °C	0.5m-2km vertical resolution	0-100 m/s	100	6	1	Global	100	I
Relative humidity profile	percent	±10%	5 layers between the surface and 10 km	1-100%	100	6	1	Global	100	I
Cloud top height	km	±0.5	—	0-20	3	3	0.5	Global	100	I
Precipitation	mm	±10%	--	0-50	6	0.5	1	Global	100	I
Temperature profiles	°C	Tropos. ±0.5-1 °C Stratos. ±1-2 °C	1-3 km vertical resolution	-110 °C to 50 °C	50	6	1	Regional	50	I
Wind profiles	speed: m/s dir: deg.	Tropos. ±1-2 m/s ±10 °C; Stratos. ±2-3 m/s, ±10 °C	1-3 km vertical resolution	0-100 m/s	50	6	1	Regional	50	I
Relative humidity profiles	percent	±10%	500 m resolution, surface - 2 km; 4 layers, 2 - 10 km	0-100%	50	6	1	Regional	50	I
Cloud top height	km	±0.5	--	0-20	50	3	0.5	Regional	50	I
Precipitation	mm	±10%	—	0-50	50	6	0.5	Regional	50	I

* I - Immediate need

Table V-3
OAR Composite Data Requirements (1985-2000) - Climate

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Sea surface temperature	°C	±0.1 °C	0.1	-2 to 35	50	Weekly	10 days	Global		I
Surface velocity wind direction	s = m/s degrees	±0.5 m/s 10 °C	0.5 5,10	0-75 m/s 0-360	100	Weekly	10 days	Global		I
Sea surface topography	cm	±1 cm	1	1-30	100	Weekly	10 days	Global		I
Precipitation	mm/wk	±2 mm/wk	2	2-500	100	Weekly	10 days	Global		I
Cloud cover				—	10	12	6	Global	100	I
Liquid water	kg/m^2	0.1			10	12	6	Global	100	I

* I - Immediate need

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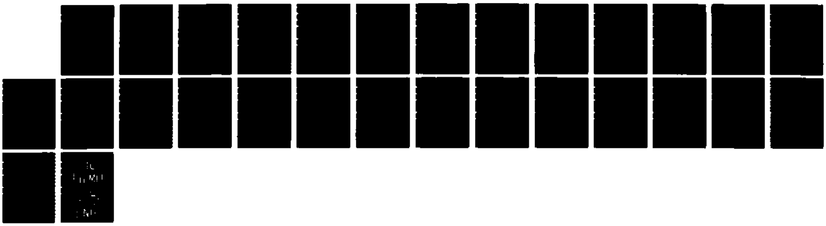

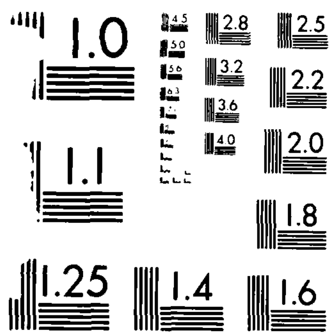

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

Table V-4
OAR Composite Data Requirements (1985-2000) - Marine Resources

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Ice extent	km	1	1	—	1	Daily	12	50°N-90°N all long.		I
Ice thickness	cm	10			1	3 times/wk	12	50°N-90°N all long.		I
Ice albedo	percent	3-5%			1	Daily	12	50°N-90°N all long.		M
Ice surface	°C	1			10-20	3 times/wk	12			
Ice concentration		5-10%			10-20	3 times/wk	12			
Snow cover extent	km	5%			10-20	Weekly	12			
Snow cover moisture equivalent	cm	1 cm**			10-20	Weekly	12			
Soil moisture	cm	1 cm**			10-20	Weekly	12			
Aquatic plant biomass					< 1	Weekly	12			

* I - Immediate need
M - Midterm, early 1990's

** Equivalent water depth

Table V-5
OAR Composite Data Requirements (1985-2000) - Marine Observations and Predictions

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delays (hours)	Coverage	Grid (km)	Priority*
Sea surface temp. (SST)	°C	±0.5 °C		-2 to 35	1	12	12	Mesoscale		I
Currents	cm/s degrees	1,5 10°	2,5 1°,10°	0-250 0-360	1,10,100	3,6,24	12	Coastal/ global	100	I
Surface waves	height: m dir: deg.	0.3/10% 10°	0.2,0.3 5°,10°	0-30 0-360	5	3,6,24	3,12	Coastal/ global	10;100	I
Surface winds	s=m/s d=degrees	0.2,1,2 10°	0.5 5°	0-75 0-360	5	6,12	3,6	Coastal/ global	100	I
Precipitation rate	cm/hr	1	10%	0-10	1,10,50, 100	12,18,24	3	Coastal/ global	100	M
Chlorophyll	g/1	30%	10%	0.01-100	0.1,0.4, 10	24,48	6,24, 48	Coastal/ global	10,25,50	M
Surface air temperature	'C	0.5,1	0.1,0.2	-40 to 35	25,50,100	3,12,24	3	Coastal/ global	100	I
Salinity	ppt	0.1,0.2, 1	0.05,0.1	30-40	2,10,50, 200	3,24	3,12	Coastal/ global	10	M
Tides	cm	2,5,20	1,5	0-1500	0.5,100	3,6	3,24	Regional Coastal/ global	—	I

* I - Immediate need
M - Midterm, early 1990's

Table V-6
OAR Data Transmission and Verification Requirements

Scientific Progress	Transmission Interval	GOES Uplink/ Downlink	Platform Positioning	Position Accuracy	Temporary Data Storage
Climate	12 h	Yes/Yes	Yes	1 km	Yes
Marine services	12 h	Yes/Yes	Yes	1 km	Yes
	Event-activated	Yes/Yes	Yes	1 km	Yes
Marine assessment	12 h	Yes/Yes	Yes	1 km	Yes
	Event-activated	Yes/Yes	Yes	1 km	Yes

Table V-7
OAR Composite Data Requirements (1985-2000) - Geostationary Orbit Data Products Requirements

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
Flare location	solar degrees lat., long.	0.5°	0.5°	±50,360	3000	0.1	0.1	Sun	NA	I
Flare area (H alpha)	millionths solar hemis.	20	10%	1-2500	3000	0.1	0.1	Sun	NA	M
Flare x-ray flux	W/m^2	$5x10^{-4}$	10^{-5}	$10^{-1}-10^{-4}$	Whole sun	0.001	0.001	Sun	NA	I
Flare x-ray duration	minutes	1	1	1-300	Whole sun	0.01	0.01	Sun	NA	I
Flare start time	hours, minutes universal time	1	1	NA	Whole sun	0.01	0.01	Sun	NA	I
Sunspot location	solar degrees lat., long.	0.5°	0.5	±50,360	1500	4	0.5	Sun	NA	M
Sunspot type	standard McIntosh classes	NA	NA	NA	1000	4	0.5	Sun	NA	M
Sunspot areas	10^{-6} hemisphere	20	10%	1-6000	1500	4	0.5	Sun	NA	M

* I - Immediate need
M - Midterm, early 1990's

Table V-7 (continued)
OAR Composite Data Requirements (1985-2000) - Geostationary Orbit Data Products Requirements

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
CME** location	solar degrees lat., long.	0.05 °C	0.3 °C	±90,360	75,000	0.1	0.1	Sun	NA	I
CME x-ray flux	W/m^2	$5x10^{-4}$	10^{-5}	10^{-1}-10^{-4}	Whole sun	0.1	0.1	Sun	NA	I
CME x-ray duration	minutes	1	0.5		Whole sun	0.01	0.01	Sun	NA	I
CME start time	hours, minutes universal time	1	0.5	NA	Whole sun	0.01	0.01	Sun	NA	I
SDF*** location	solar degrees lat., long.	2	2	±90,360	3000	0.01	0.01	Sun	NA	M
SDF start time	hours, minutes universal time	5	1	NA	Whole sun	0.01	0.01	Sun	NA	I
X-ray back-ground flux	W/m^2	10^{-7}	$\pm10^{-8}$	10^{-1}-10^{-7}	Whole sun	0.001	0.01	Sun	NA	I
Type II radio burst frequencies	MHz	5	1	40-500	Whole sun	0.01	0.01	Sun	NA	M
Type IV radio burst frequencies	minutes	1	1	1-300	Whole sun	0.01	0.01	Sun	NA	M

* I - Immediate need; M - Midterm, early 1990's
** Coronal mass ejection
*** Sudden disappearance of filament

Table V-7 (continued)
OAR Composite Data Requirements (1985-2000) - Geostationary Orbit Data Products Requirements

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
CME** location	astronomical units (A.U.)	0.1	0.1	0.3-2	$2x10^{-7}$	4	0.5	Solar wind	NA	I
CME mass	gram	10^{14}	10^{14}	10^{13}-10^{17}	$2x10^{-7}$	4	0.5	Solar wind	NA	I
Vector magnetic field	gamma = 1 mt	0.5	0.5	±1200 DC ±400 AC	NA	Continuous	NA	In situ	NA	M
Total energy (0.3<E<20 keV)	keV $cm^{-2}s^{-1}$	25%	1%	0.1-1000	NA	1/3600	None	In situ	NA	I
Proton flux (30<E<500 MeV)	keV $cm^{-2}s^{-1}$	25%	1%	10-10^5	NA	1/3600	None	In situ	NA	I
Energetic electrons (30<E<2Mev)	keV $cm^{-2}s^{-1}$	25%	1%	1-10^{10}	NA	1/3600	None	In situ	NA	I
Total electron content	$10^{14}m^{-2}$	1	0.1	10-10^4	10	Continuous	NA	Whole ionosphere	NA	M

* I - Immediate need; M - Midterm, early 1990's
** Coronal mass ejection

Table V-7 (continued)
OAR Composite Data Requirements (1985-2000) - Polar Orbit Data Products Requirements

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
X-ray aurora locations	degrees lat., long.	1,1	0.1	GM 50-70	100	1	0.1	Earth polar region	NA	I
EUV aurora locations	degrees lat., long.	1,1	0.1	GM 50-80 360°	100	1	0.1	Earth polar region	NA	M
Vis aurora locations	degrees lat., long.	1,1	0.1	GM 50-70	100	1	0.1	Earth polar region	NA	M
Total energy (0.3<E<20 keV)	ergs $cm^{-2}s^{-1}$	0.01 25%	0.001 1%	0.1-1000	100	1/3600	Real time	In situ	NA	I
Protons (30keV<E <100MeV)	ergs $cm^{-2}s^{-1}$	25%	1%	10^2-10^5	100	1/3600	Real time	In situ	NA	I
Electrons (30keV<E<2MeV)	ergs $cm^{-2}s^{-1}$	25%	1%	1-10^{10}	100	1/3600	Real time	In situ	NA	I
Vector magnetic field	nT	0.5	0.5	$\pm 10^3$	100	1/3600	Real time	In situ	NA	I
Total electron content	$10^{14}m^{-2}$	1	0.1	10-10^{14}	10	Continuous	NA	Whole ionosphere	NA	M

* I - Immediate need
M - Midterm, early 1990's

Table V-7 (continued)
OAR Composite Data Requirements (1985-2000) - Polar Orbit Data Products Requirements

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
EUV flux input	W/m^2	20%	5%	10^{10}-$2.5x10^{10}$	Whole sun	4	0.5	Sun	NA	M
EUV emission location	solar degrees lat., long.	3	1	±90,360	50,000	4	0.5	Sun	NA	M
Chromospheric flow vectors	direction (degrees)	2	5	0-360	3500	24	6	Sun	NA	M
	magnitude (m/s)	5	10	5-2000				Sun	NA	M
XCH** location	solar degrees lat., long.	5	5	±90,360	75,000	4	0.5	Sun	NA	I
XCH** x-ray flux	W/m^2	10^{-7}	10^{-8}	10^{-5}-10^{-7}	75,000	4	0.5	Sun	NA	M
Vector magnetic field strength	degrees	5	10	0-360				Sun	NA	L
	gauss	20	20	20-4000	2000	4	0.5	Sun	NA	L
Longitudinal magnetic field strength	gauss	20	20	20-4000	2000	4	0.5	Sun	NA	M
								Sun	NA	M
Magnetic polarity neutral line locations	solar degrees	0.5	0.2	±50,360	1000	4	0.5	Sun	NA	M
Magnetic arch locations	solar degrees lat., long.	1	1	±50,360	2000	4	0.5	Sun	NA	I

* I - Immediate need
M - Midterm, early 1990's
L - Late 1990's
** X-ray coronal hole

Table V-7 (concluded)
OAR Composite Data Requirements (1985-2000) - Libration Orbit Data Products Requirements

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
Solar wind bulk speed	km/sec	10	10	300-1000	NA	0.01	0.01	In situ	NA	I
Proton density	$1/cm^3$	1	0.1	1-100	NA	0.01	0.01	In situ	NA	I
Proton flux > 10 MeV	$cm^{-2}s^{-1}sr^{-2}$**	10^2	10^2	10^2-10^5	NA	0.1	0.01	In situ	NA	I
Magnetic field components	gamma = 1 nT	1	0.1	5-200	NA	1/3600	0.01	In situ	NA	I
Energetic flux (0.1 MeV-1 BeV)	$cm^{-2}s^{-1}sr^{-1}$				NA	1/3600	0.01	In situ	NA	I
Energetic electron flux (30keV-3MeV)	$cm^{-2}s^{-1}sr^{-1}$				NA	1/3600	0.01	In situ	NA	I
High-Z flux (25 MeV-1 BeV)	$cm^{-2}s^{-1}sr^{-1}$				NA	1/3600	0.01	In situ	NA	I
Type II radio burst frequencies	kHz	25%	10%	30-2000	15 degrees	0.01	0.01	Solar wind	NA	I

* I - Immediate need
** steradian

Table V-8
OAR Composite Data Requirements (1985-2000) - Polar and Geostationary Platform Requirements

Requirement	Platform	Description	Priority
Advanced Data Collection System (Image-size arrays)	On Geostationary and Polar orbiters	Ability to interrogate and dump remote data caches to the spacecraft and back to the ground	Handle 10 megabits of data
Quick-reaction pad	On Geostationary and Polar orbiters	Slot reserved on the instrument manifest list for *late-arriving* sensors, which fit standardized budgets, for instrument development and concept development	Set aside standard budgets of 7 watts

VI. SATELLITE REQUIREMENTS
OF THE
NATIONAL MARINE FISHERIES SERVICE

VI. SATELLITE REQUIREMENTS OF THE NATIONAL MARINE FISHERIES SERVICE

Satellite remote sensing of the oceans is becoming increasingly important to fishery management and research. Variations in oceanic conditions cause fluctuations in the recruitment, distribution, abundance, and harvest of fish stocks. To understand and eventually predict these fluctuations, synoptic information on the ocean environment, rather than the mean or average conditions, is needed. Satellite measurements of ocean environmental parameters, combined with conventional data collection techniques, provides a method for obtaining the synoptic information required.

A. APPLICATIONS OF SATELLITE DATA

The use of satellite remote sensing in oceanography has expanded considerably in recent years. The National Marine Fisheries Service (NMFS) has adapted the technology for applications in operational and research programs.

At the Southeast Fisheries Center, Seasat-A scatterometer data were used to compute wind-induced surface currents and to delineate areas of upwelling and downwelling. This information is valuable in determining the direction of transport of fish eggs and larvae. Shrimp, for example, spawn offshore and depend on currents to transport their eggs and larvae into estuarine nursery grounds where the shrimp mature. If surface currents are moving offshore during peak spawning periods, the number of shrimp entering the estuaries will be reduced and the fishery adversely impacted. Refinement of this technique will provide a valuable tool for forecasting recruitment and yields of shrimp and other species dependent on this transport mechanism.

The Southeast Center uses data from the Coastal Zone Color Scanner (CZCS) to detect and map areas of hypoxia in the northern Gulf of Mexico. Hypoxia, an environmental condition characterized by bottom water oxygen concentrations near zero, is not well understood and occurs frequently in the northern Gulf. Location of areas of hypoxia is important to fisheries because waters with low oxygen content will support few, if any, shrimp or finfish, and may block the normal migration patterns of these animals.

Additionally, the Southeast Center uses satellite data transmission links to relay fishery and environmental survey data from survey ships to data users. Daily transmissions of survey data are made from the ships to shore-based computers through the Applications Technology Satellite (ATS-3) and through portable Argos transmitters. The data are summarized

on charts and distributed weekly to fishermen, fishing associations, State fishery management organizations, and others for various applications.

The ATS system also was used by fishery scientists participating in the Antarctic Marine Ecosystem Research at the Ice-Edge Zone (AMERIEZ) program to study physical and biological processes active during the retreat of the ice edge. Fisheries scientists received NASA/Goddard near-real-time ice maps derived from Nimbus-7 microwave data. The maps were sent to research vessels by means of the ATS system. In return, the scientists at sea transmitted wind data to NASA/Goddard for use in analyzing changes in ice cover.

At the Southwest Fisheries Center, CZCS and AVHRR data are used to produce charts showing the location of ocean color boundaries or fronts. These charts are used widely by tuna fishermen to locate favorable areas for fishing. Studies at the center have shown that the tuna tend to concentrate in the warm, bluish oceanic waters along the fronts. Very few or no tuna are found in the cooler, greenish coastal waters. Recently, the satellite information has been particularly useful in locating fish. Because of the abnormal warming of ocean waters resulting from the El Niño phenomenon, many fish stocks were displaced northward from their usual habitats. The satellite data provided the information required to locate the areas to which the fish migrated.

The CZCS imagery also is used by the Southwest Center to describe ocean processes related to the spawning of northern anchovy. Imagery was collected coincident with fine-grid oceanographic ship observations. Preliminary results indicate that anchovy avoid areas of low chlorophyll concentrations, presumably because of insufficient food availability. Additionally, CZCS data are being used to investigate the distribution and abundance of juvenile salmon off the Oregon-Washington coast.

The Northeast Fisheries Center has joined with a community of Federal, State, and private users of remote-sensing data to form the Northeast Area Remote Sensing System (NEARSS) Association. The association focuses on solutions to the problems of member institutions in acquiring and using, efficiently and economically, remote-sensing data and data analysis techniques. Through contributions from these institutions, a regional net for distribution of the analog satellite images transmitted by NOAA over the GOES-Tap has been established.

The long-term NEARSS goal is to obtain near-real-time access to full-resolution digital data from NOAA's polar-orbiting satellites.

The Coastal Habitat Assessment Research Mensuration (CHARM) Program at the Northeast Center is designed to respond to the national goal of zero net loss of wetlands productivity. Wetlands provide and support habitats suitable as spawning, nursery, and feeding areas for 96 percent of the commercial fisheries and 50 percent of the recreational catch. The approach is to use Landsat data to provide a uniform format to classify and monitor wetlands, and to integrate the results to determine the effects on fisheries.

Satellite infrared imagery also is used by the Northeast Center to delineate the areas affected by sediment plumes from the Chesapeake, Delaware, and Raritan Bays. The plumes contain biostimulants, contaminants, and other materials that can have an effect on fishery resources.

The remote-sensing activities at the National Marine Fisheries Service are designed to improve the management and utilization of coastal fishery resources. Remote-sensing data, in conjunction with traditional data bases, have provided a valuable tool for describing broad ocean area physical processes that may affect fishery resources. As the data flow from satellite ocean sensors increases over the next few years, NMFS will continue to develop new techniques that can be used to incorporate these data into operational and research programs.

B. REQUIREMENTS

Fisheries applications require satellite data on all measurable oceanographic environmental parameters, with particular emphasis on sea surface temperature, surface currents, and ocean color. The need exists for real-time and archived data on these parameters for the entire U.S. Exclusive Economic Zone (EEZ), as well as those open ocean areas of importance to U.S. tuna fishing activities and marine mammal migrations. These data are required in studies to:

- Improve the efficiency of commercial fishing vessel operations
- Relate the dynamics of ocean currents and fronts to fish abundance, availability, and behavior
- Improve estimates of primary productivity and fish yield
- Determine migration patterns of highly mobile species (tuna, billfish, and marine mammals)
- Predict fish stock availability
- Improve fish harvesting

- Measure loss of spawning habitat and monitor changes in wetland use
- Improve resource assessments
- Improve fishery conservation and management techniques
- Chart areas of polluted waters or areas of adverse environmental conditions that may affect fishery resources

NMFS satellite data requirements are shown on Table VI-1.

Table VI-1
NMFS Composite Data Requirements (1985-2000)

Parameter	Units	Absolute Accuracy	Precision	Range	Horizontal Resolution (km)	Frequency (hours)	Delay (hours)	Coverage	Grid (km)	Priority*
Wind:										
Speed	m/sec	2	0.5	0-75	50-100	16	3	Selected coastal and ocean areas	200	I
Direction	degrees	30	10°	0-360					20	I
SST	°C	0.5	0.2	-2 to 35	2-10	3	3		10	I++
Color:										
Chlorophyll	mg/m^3	10%	10%	0.1-20	0.5	48	3	"	10	I++
Waves:										
Significant ht.	m	0.5	0.5	0-25	25-50	3	3	"	100	M
Direction	degrees	10	10	0-360	25-50					
Sea ice:										
Cover	percent	15	15	-	25	48	3	--	20	M
Thickness	m	1	0.5	-	25			Selected coastal and ocean areas	50	
Surface currents										
Speed	cm/sec	25		0-500	25-50	3	3		100	I++
Direction	degrees	30	NA	0-360	25-50					I++

* I - Immediate need
M - Midterm, early 1990's

VII. SUMMARY

As shown in the previous chapters, NOAA user requirements for environmental satellite data and services overlay and interlock with each other in many ways. Satellites enable NOAA users to obtain frequent, high-resolution data on a global basis for a multitude of operational and research purposes. Many scientific disciplines are served by data from any given instrument. This results in users from several disciplines opting for observations in the same spectral channels, with their requirements differing only in terms of details such as resolution, coverage, frequency, timeliness, and the like.

This overlap of user requirements makes it possible to serve a wide range of applications from a single design for a satellite sensor or service. In many instances, such as global cloud cover, environmental satellites are the only cost-effective means of obtaining data that have the space and time resolutions needed for certain applications. In these instances, the satellite's design accommodates the highest priority requirements and accounts for similar, but differing, needs to the extent possible. For example, GOES observations of severe weather processes serve weather forecasters and researchers alike, but the design of GOES favors operational forecasting needs in terms of surface spatial resolution and the frequency of observations. Researchers benefit from the routine data that GOES provides, but a design capability also is provided that enables the more frequent observations needed for research purposes. This research capability is exercised whenever practical.

Developing effective operational satellite systems for supporting environmental programs requires that the mix of ground-based and space-based observing systems blend efficiently and complement each other. With rare exceptions, in situ methods of measurement give more accurate results than remote sensing. The advantage of space remote sensing is that it provides economic global observations of a myriad of parameters, measured with good accuracy by consistent instruments. The NOAA requirements presented in this paper will help define the future mix of observing systems. Polar-orbiting and geostationary satellites, along with ground and ocean systems such as NEXRAD, ASOS, ART, Profilers, ocean buoys, and shipboard measurements, will comprise an effective, integrated future NOAA observing system.

The ground processing and distribution of satellite data is

another critical element in the satisfaction of user requirements. NOAA users, and most others, look to NESDIS to preprocess raw sensor data and convert them to calibrated, Earth-located information expressed in geophysical units, such as temperature or distance. The process requires that the signals from the instrument be interpreted in terms of sensor characteristics (calibration), corrected for atmospheric and other influences, and assigned a geographic location. The step from calibrated, corrected, Earth-located values to geophysical units may involve mixing or comparing data from several channels or from other instruments, statistical processing, or other complexities. The efficiencies of centralized preprocessing are very high. From the point of view of most users, the preprocessed satellite-derived product is all that is required for their applications purposes.

The requirements of NOAA users express, explicitly r implicitly, the need for distributed data handling and processing systems. This data preprocessing, to the highest practical levels, should take place at central locations. The computer facilities at field locations should be connected to these preprocessing centers to access scheduled product deliveries and tap the data base on demand. The computer capabilities at the field sites should be reserved for analysis and forecasting functions and should be protected from duplicating preprocessing tasks that are best performed centrally. This requirement is a general one, applying to products derived from satellite, ocean, and ground-based observing system data, as well as to real-time and retrospective applications.

Swift, responsive data relay between its nodes will be a design imperative of the future NOAA distributed data handling system. NOAA plans to improve services and contain real operating costs by taking advantage of emerging computer, telecommunications, and other technological opportunities for consolidating field operations and eliminating much of the manual intervention necessary in the present system. The full benefits of the distributed system can be realized only if data products (scheduled, on-line, and off-line) reach users with the accuracy and in the formats and time frames they need. Properly bringing this about is a significant system design challenge and will influence the selection of the hardware and the software construction for the physical system.

Satellites have been a valuable source of global environmental data for the past quarter-century. Throughout the period, they have made strong contributions to operational and research programs and their data have blended well with those

from other observing systems. Within NOAA, the advantages of satellites in operational and research environmental programs, and fisheries management programs, are very great today and are projected to increase in the future. The outlook is for technology that will enable NOAA to develop an effective, synergistic observing system, including satellites, that will satisfy the varied data demands of NOAA's missions.

APPENDIX A

CURRENT AND PLANNED NOAA SATELLITES

NOAA's Polar-orbiting Operational Environmental Satellites (POES):

The current POES series has spacecraft in sun-synchronous polar orbits at 833 and 870 km. Imaging, surface temperatures, and cloud mapping are provided by a 5-channel visible and infrared radiometer with 1.1 km resolution. Three instruments provide atmospheric sounding data: a 20-channel high-resolution infrared sounder, a 3-channel selective absorption sensor to determine weighting functions at 15 μm wavelengths, and a 4-channel Dicke microwave radiometer. Additionally, these satellites monitor solar particle flux at the spacecraft and provide for the collection and relay of data from fixed and moving automatic sensor platforms. Satellite sensor data are broadcast continuously for intercept by any ground station within range.

The next POES series will include the Advanced Microwave Sounding Unit (AMSU), which will replace the 3-channel infrared absorption and 4-channel Dicke microwave sounding instruments now in use. The AMSU will provide 15 channels of coverage in the 20-90 GHz range and 5 channels in the 90-184 GHz range. It will add new capabilities for atmospheric humidity measurements, distinguishing sea ice, and gathering information about snow thickness and soil moisture. AMSU will make soundings more accurate and will permit sounding through clouds over areas with active weather patterns. The current imager will be improved by adding one or two new channels and sharpening others; some channel changes also are planned for the High-Resolution Infrared Radiation Sounder (HIRS). A major planned sensor addition is the Ocean Color Instrument (OCI), which probably will be introduced on an early spacecraft in this series. The other functions and services of the series will remain as they are currently.

NOAA's Geostationary Operational Environmental Satellites (GOES):

The current GOES series provides imaging and sounding data via a single instrument. A visible channel (0.55 to 0.75 μm) and 12 IR channels (from 3.9 to 15.0 μm) are provided. Subpoint resolution is 1 km in the visible and 7 or 14 km in the IR, determined by detector selection. The single optical system of the instrument precludes its simultaneous operation in both

imaging and sounding modes. GOES are equipped to monitor the flux of solar X-rays, alpha particles, protons, and electrons at the spacecraft. They are provided with data collection systems for the relay of information from automatic sensor platforms. Sensor data are broadcast continuously for receipt by ground stations. A GOES service is the retransmission of meteorological charts and other environmental information, including satellite imagery, in facsimile format.

The next GOES series will provide separate imaging and sounding instruments, so that these functions can occur simultaneously. More imaging and sounding channels will be included. The other capabilities and services of the current series will be continued.

NOAA's Land Remote-Sensing Satellites (Landsat):

Current Landsat spacecraft provide Earth-imaging through two separate instruments. The Multi-Spectral Scanner (MSS) is a 4-channel instrument that provides visible and infrared data at 80 m subpoint resolution. The other, the Thematic Mapper (TM), is a 7-channel visible and infrared spectrometer that provides data at 30 m resolution, except for 120 m resolution in the thermal infrared band. Two spacecraft of the current series are in orbit: Landsat 4 and 5. The orbit is sun-synchronous at 705 km, providing a 16-day repeat cycle for revisits to the same Earth scene. Direct data broadcasts are provided to non-Federal ground stations, which pay a data access fee and enter into formal agreements covering the receipt and distribution of Landsat data.

The Landsat system is being commercialized. Under the expected conditions of commercialization, the U.S. Government will continue services from Landsat 4 and 5 through their design lifetimes (probably mid-1987) by contracting with a private company for the management and day-to-day operation of the present system. The same company also will be responsible for the marketing of Landsat data. The company will continue service beyond Landsat 5 by launching an improved Landsat 6, in late 1988, and the follow-on Landsat 7, probably in late 1992. Landsat 6 and 7 will provide TM-class instruments and MSS emulators. The emulators will convert the TM-like data to MSS format. The new satellites also will provide a panchromatic imager with 15 m subpoint resolution. A 5-year lifetime is projected for Landsat 6 and 7.

APPENDIX B

GLOSSARY OF ACRONYMS

AFOS	-	Automation of Field Operations and Services
AMERIEZ	-	Antarctic Marine Ecosystem Research at the Ice-Edge Zone
AMSU	-	Advanced Microwave Sounding Unit
APT	-	Automatic Picture Transmission
Argos	-	French Data Collection and Platform Location System
ART	-	Automated Radio Theodolites
ASAP	-	Automated Shipboard Aerological Programme
ASDAR	-	Aircraft to Satellite Data Relay
ASOS	-	Automated Surface Observing System
ATS	-	Applications Technology Satellite
AVHRR	-	Advanced Very High Resolution Radiometer
AWIPS-90	-	Advanced Weather Interactive Processing System (for the 1990's)
CAC	-	Climate Analysis Center
CBS	-	Commission for Basic Systems
CDA	-	Command and Data Acquisition
CDDF	-	Central Data Distribution Facility
C&GS	-	Charting and Geodetic Services
CHARM	-	Coastal Habitat Assessment Research Mensuration
C-MAN		Coastal-Marine Automated Network

CONUS	-	Contiguous 48 States
CTD	-	Conductivity and Temperature With Depth
CZCS	-	Coastal Zone Color Scanner
DCP	-	Data Collection Platforms
DCS	-	Data Collection System
DMSP	-	Defense Meteorological Satellite Program
DOD	-	Department of Defense
DOI	-	Department of the Interior
DOT	-	Department of Transportation
DSB	-	Direct Sounder Broadcast
EEZ	-	Exclusive Economic Zone
ERL	-	Environmental Research Laboratories
ERS-1	-	ESA Remote-Sensing Satellite
ESA	-	European Space Agency
FGGE	-	First GARP Global Experiment
GAC	-	Global Area Coverage
GARP	-	Global Atmosphere Research Program
GCM	-	General Circulation Model
GMS	-	Geostationary Meteorological Satellite
GMT	-	Greenwich Mean Time
GOES	-	Geostationary Operational Environmental Satellites

GOES-Next	-	Next Generation Geostationary Satellites
GOS	-	Global Observing System
GPS	-	Global Positioning System
GTS	-	Global Telecommunications System
HIRS/2	-	High-Resolution Infrared Radiation Sounder
HRPT	-	High Resolution Picture Transmission System
IR	-	Infrared
JIC	-	Joint Ice Center
JPL	-	Jet Propulsion Laboratory
LAC	-	Local Area Coverage
Landsat	-	Land Satellite
LFM	-	Limited Fine Mesh
MBL	-	Marine Boundary Layer
MCSST	-	Multi-Channel Sea Surface Temperature
MLD	-	Mixed Layer Depth
MSS	-	Multi-Spectral Scanner
MSU	-	Microwave Sounding Unit
NASA	-	National Aeronautics and Space Administration
NDBC	-	NOAA Data Buoy Center
NEARSS	-	Northeast Area Remote Sensing System Association

NESDIS	-	National Environmental Satellite, Data, and Information Service
NEXRAD	-	Next Generation Weather Radar
NHC	-	National Hurricane Center
NMC	-	National Meteorological Center
NMFS	-	National Marine Fisheries Service
NOAA	-	National Oceanic and Atmospheric Administration
NOS	-	National Ocean Service
NOSS	-	National Oceanic Satellite System
N-ROSS	-	Navy Remote Ocean Sensing System
NSSFC	-	National Severe Storms Forecast Center
NWS	-	National Weather Service
OAR	-	Office of Oceanic and Atmospheric Research
OCEANFAX	-	Ocean Facsimile (proposed)
OCI	-	Ocean Color Instrument
OH	-	Office of Hydrology
OMA	-	Oceanography and Marine Assessments
OPC	-	Ocean Products Center
OSC	-	Ocean Service Center
OSD	-	Ocean Services Division
OTSR	-	Optimum Track Ship Routing
POES	-	Polar-orbiting Operational Environmental Satellites
PROFS	-	Program for Regional Observing and Forecasting Services

RFC - River Forecast Center

SANBAR - Sanders Barotropic Model

SAR - Synthetic Aperture Radar

SEAS - Shipboard Environmental Data Acquisition System

Seasat - Sea Satellite

SEL - Space Environment Laboratory

SESC - Space Environment Services Center

SFSS - Satellite Field Services Station

SIM - Satellite Interpretation Message

SMMR - Scanning Multi-channel Microwave Radiometer

SOWM - Spectral Ocean Wave Model

SST - Sea Surface Temperature

SSTA - Sea Surface Temperature Anomaly

SSU - Stratospheric Sounding Unit

STORM - Storm-scale Operational and Research Meteorology Program

SWIS - Satellite Weather Information Service

TIROS - Television and Infrared Observation Satellite

TM - Thematic Mapper

TOGA - Tropical Ocean Global Atmosphere Program

TOVS - TIROS Operational Vertical Sounder

UHF - Ultra-High Frequency

VAS	-	VISSR Atmospheric Sounder
VISSR	-	Visible and Infrared Spin-Scan Radiometer
WEFAX	-	Weather Facsimile
WI-CDA	-	Wallops Island Command and Data Acquisition
Windsat	-	Wind Satellite
WLMS	-	Water Level Measurement System
WMO	-	World Meteorological Organizataion
WSFO	-	Weather Service Forecast Office
XBT	-	Expendable Bathythermograph
XCP	-	Expendable Current Profilers
XCTD	-	Expendable Conductivity/Temperature/Depth Profilers

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